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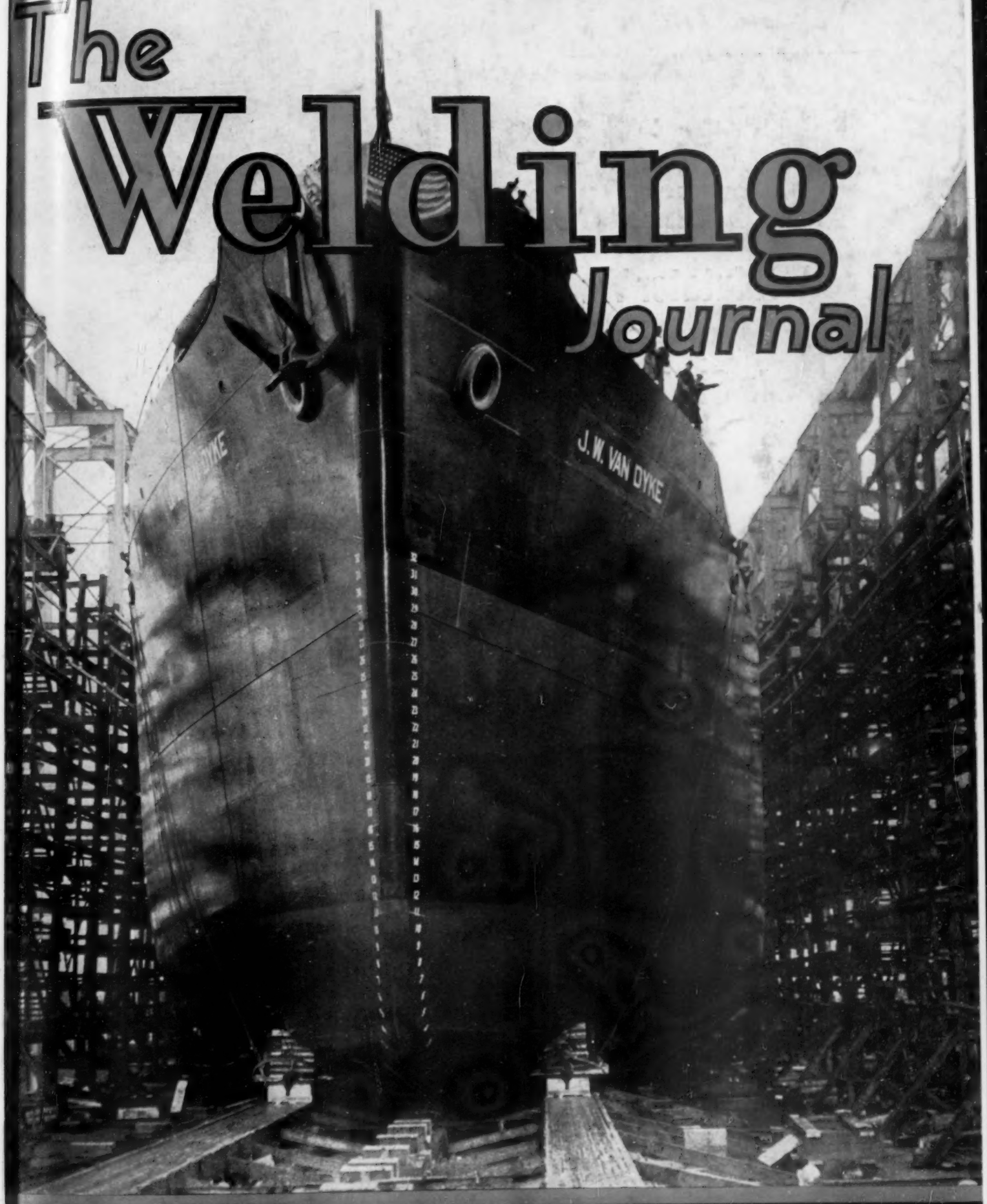
JANUARY, 1938

The Welding Journal



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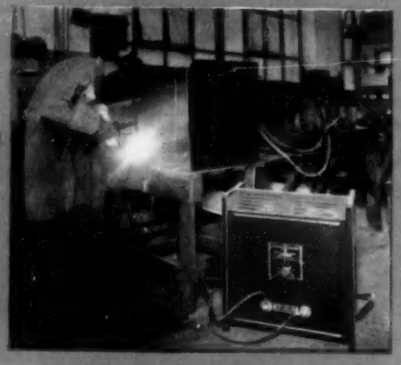

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September 10, 1947

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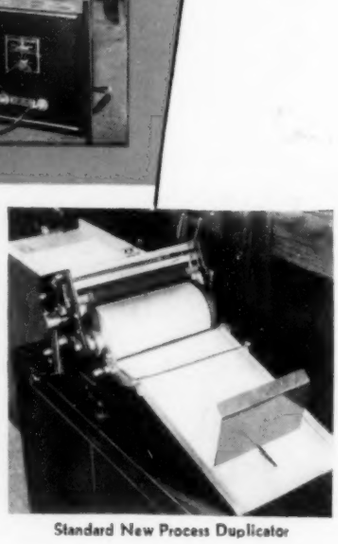

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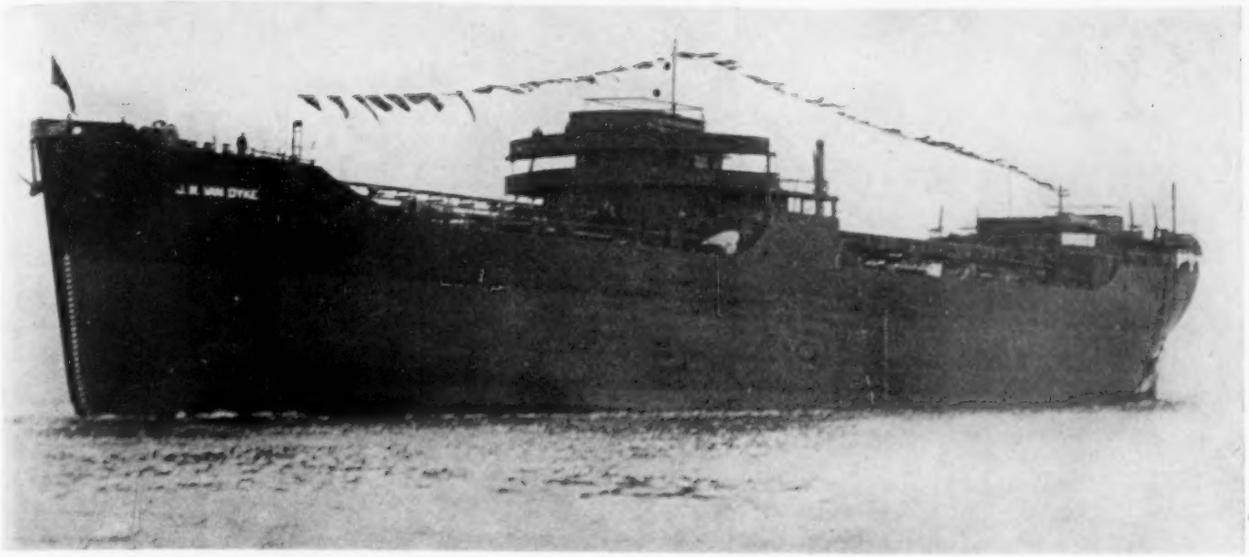

The "J. W. Van Dyke" in the Delaware, Just After Leaving the Ways of the Sun Shipbuilding and Dry Dock Company

THE J. W. VAN DYKE*

THE launching Nov. 20th that the Sun Shipyards of The Atlantic Refining Company's new tanker, the "J. W. Van Dyke," added to the American merchant marine an oil carrier that on one trip will be able to carry more oil than was produced in any one day between 1878 and 1909. The vessel, named in honor of the company's chairman of the board, was christened by Mrs. W. M. Irish, whose husband retired as Atlantic's president in May of this year. (See cover.)

The "J. W. Van Dyke" is the world's largest welded ship and the first American-built turbo-electric tanker.

Her deadweight capacity is 18,500 tons; her displacement at loaded draft is 23,898 tons. Cargo capacity is 6,552,000 gallons. The vessel has an over-all length of 541 feet five inches, a length of 521 feet two inches, between perpendiculars, a molded beam of 70 feet, a molded depth of 40 feet and a draft of 29 feet six inches. Capacity of the fuel oil bunkers is 380,940 gallons.

Turbo-electric engines, developing 5000 horsepower, will give the ship a speed of 13.25 knots enabling her to make the trip between Philadelphia and Texas Gulf ports in the unusually fast time of six days. Pumping equipment will make possible the discharge of cargo at the rate of 630,000 gallons an hour, approximately three times the usual discharge rate.

The vessel is built on the longitudinal bracketless system of construction with two longitudinal fore and aft bulkheads. There are nine center tanks, and nine wing tanks on each side. Tanks are equipped with automatic vent and vacuum valves which operate automatically to relieve vacum or excessive pressure. The Butterworth system will be used in cleaning the tanks.

The main turbo-generating unit supplies steam from two boilers equipped with automatic combustion control. The boilers operate at a pressure of 625 pounds per square inch and at a steam temperature of 835° F.

Every possible provision has been made to assure the health and comfort of the 8 officers and 26 men that the "J. W. Van Dyke" will carry. All aft crew and engineer officers' quarters are mechanically ventilated and have automatic heat control. Unusually light and airy lounges are provided for both officers and crew.

The bridge deck amidship contains the first, second and third deck officers' quarters, the officers' lounge, a well-equipped hospital, the radio room and the radio operators' quarters. The captain's office and quarters are on the boat deck. The chart room and wheel house are on the navigating bridge.

Quarters for the engineer officers, together with the officers' mess, crew's mess, galley and engineers' laboratory are on the poop deck. On the upper, or main deck, are the crew's quarters, refrigerating rooms, store rooms and two foam houses—one amidship and one aft. The crew's lounge is on the after boat deck.

Construction of a welded tanker is not a new departure for the company. In fact Atlantic was one of the pioneers in this field. One of the first all-electrically-welded, self-propelling vessels to be built in this country was the "White Flash," a tanker with a length of 201 feet two inches over-all, a beam of 34 feet and a cargo capacity of 315,000 gallons. The contract for the "White Flash" was placed in November 1930. This was followed three years later by a twin ship, the "Franklin." Both ships fully lived up to expectations and demonstrated the practicality of substituting welding for riveting.

The addition of the new "J. W. Van Dyke" to the Atlantic tanker fleet, increases the number of Atlantic's tankers to 23, with a total dead weight tonnage of 233,848 tons.

* News Release, N. W. Ayer & Son, Inc.

AMERICAN WELDING SOCIETY

CODE FOR FUSION WELDING and Gas Cutting in Building Construction

PART A—STRUCTURAL STEEL

PREFACE TO 1937 EDITION

Since the Code was first issued in 1928, revisions have been made from time to time which have reflected advances in the field of structural fusion welding. The present 1937 edition incorporates the following important revisions:

1. While retaining unchanged the existing unit stresses for welds made with filler metal of Grades 20, 30 or 40 (bare or lightly coated electrodes and mild steel gas welding rods), a new set of unit stresses for welds in shear and tension are added which provide for an increase of 20 per cent when made with filler metal of Grades 2, 4, 10 or 15 (heavily coated electrodes or high-test gas welding rods). These increased unit stresses reflect the higher tensile strength, superior ductility and resistance to fatigue afforded by these grades of filler metal.

2. Qualification strength requirements for operators of welding equipment using these higher grades of filler metal are correspondingly increased 20 per cent.

3. The current specifications relating to filler metal are included.

4. New symbols for fusion welding are shown which conform to the latest Standards of the AMERICAN WELDING SOCIETY.

The following is the personnel of the Committee on Building Codes as constituted October 18, 1937:

G. D. FISH, Chairman	Consulting Engineer
MILTON MALE, Sec'y	United States Steel Corp.
J. L. ANDERSON	Air Reduction Company
H. G. BALCOM	Consulting Engineer
A. G. BISSELL	Bureau of Construction & Repair, U. S. Navy
C. T. BISSELL	National Board of Fire Underwriters
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F. EDER	R. W. Hunt Company
A. R. ELLIS	Pittsburgh Testing Laboratory
F. H. FRANKLAND	American Institute of Steel Construction
W. S. HOAR	Bethlehem Steel Company
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ANDREW VOGEL	General Electric Company
A. WEYMOUTH	Post & McCord Inc.
C. C. WHITTIER	R. W. Hunt Company
H. A. WOOFTER	Federal Machine & Welder Company

(Signed) P. G. LANG, JR., *President*

SECTION 1—GENERAL APPLICATION—(NO CHANGE)

SECTION 2—DEFINITIONS—(AS AMENDED TO DATE BY A. W. S.)

SECTION 3—MATERIALS

1. Structural steel to be welded under this code shall conform to Serial Designation A-9 (Steel for Buildings) of the current Standard Specifications of the American Society for Testing Materials.

2. Filler metal (arc-welding electrodes and gas-welding rods) shall conform to all general requirements, and to all special requirements for at least one of the grades of filler metal, provided by Serial Designation A205–37T (Iron and Steel Filler Metal), as amended to date, issued jointly by the American Society for Testing Materials and the AMERICAN WELDING SOCIETY. (See Appendix I.)

SECTION 4—PERMISSIBLE UNIT STRESSES

1. Welded joints shall be proportioned so that the stresses caused therein by loads specified in the Building Code shall not exceed the following values, expressed in Kips (thousands of pounds) per square inch:

Kind of Stress	For Welds Made with Filler Metal of Grade 2, 4, 10 or 15	For Welds Made with Filler Metal of Grade 20, 30 or 40
Shear on section through weld throat	13.6	11.3
Tension on section through weld throat	15.6	13.0
Compression (crushing) on section through throat of butt weld	18.0	18.0

Fiber stresses due to bending—etc.—(No Change).

2. In designing welded joints—etc.—(No Change).

SECTION 5—DESIGN—(NO CHANGE)

SECTION 6—WORKMANSHIP—(NO CHANGE)

SECTION 7—ERECTION—(NO CHANGE)

SECTION 8—GAS CUTTING—(NO CHANGE)

APPENDIX I
Specifications for Filler Metal

(The A.S.T.M.-A.W.S. Specification A205–37T is to be reprinted here in its entirety.)

APPENDIX II
Qualification Test for Operators of Welding Equipment

1. The minimum qualification requirement shall be the welding of test specimens of the type shown in Fig. 2 (Page 10) and specified in Paragraph 2, each specimen to be tested to failure in a reliable tension-testing machine and to develop ultimate resistance not less than

80 kips if welded with filler metal of Grade 2, 4, 10 or 15
67 kips if welded with filler metal of Grade 20, 30 or 40

Two specimens shall be welded in the horizontal welding position, two in the vertical welding position, and (in case the operator is to perform overhead welding as part of his structural work) two in the overhead welding position.

2. The form of test specimen shall be that which is shown in Fig. 2 (Page 10), consisting of four steel bars or plates connected by approximately equal fillet welds. This design of specimen is similar to one of those recommended by the Structural Steel Welding Committee in its 1931 report, except that its width is reduced from 3 inches to $2^1/_2$ inches. The bar steel shall conform to A.S.T.M. Specification A-9. The welding edges of the splice bars shall be cut flat and square and any burrs shall be removed. The bars shall be clamped securely together and tack welded in proper position with the splice bars centered on the main bars and the faces of the main bars in true planes, in preparation for the test welding. Welding shall be performed with the same process (arc or gas), the same welding procedure, and the same grade of electrode or welding rod to be used in the work—etc.—(remainder of Paragraph Unchanged).

3. The foregoing provisions—etc.—(Unchanged).

APPENDIX III
Recommended Welding Practices

Three prefatory paragraphs deleted.
General Requirements (No Change).
Special Requirements for Arc Welds
Part 1 and Part 2—(No Change).
Special Requirements for Gas Welds (No Change).

APPENDIX IV
Weld Symbols

Opposite (Fig. 21) is given a chart showing Symbols for Fusion Welding. These symbols are abstracted from the official series, prepared by the Committee on Nomenclature, Definitions and Symbols of the AMERICAN WELDING SOCIETY and approved by the Society in 1937. These symbols—etc.—(remainder of Appendix IV unchanged).

Fig. 2 (page 10). *Qualification Test Specimen.* Reduce width from 3 inches to $2^1/_2$ inches, and change all dimensions to correspond.

Table II (page 13). *Current Values and Sizes of Electrodes.* Revise captions which include old grade designations of electrodes to correspond with new filler metal grade designations.

Fig. 21. *Symbols for Fusion Welding.* Revise drawing to conform to new Symbols adopted 1937.

A.W.S. Definitions of Terms Appearing on Master Chart of Welding Processes*

Air-Acetylene Welding: A gas welding process wherein the welding heat is obtained from the combustion of air and acetylene.

Alternating Current Arc Welding: An arc welding process wherein the supply at the arc is alternating current.

Arc Brazing: An electric brazing process wherein the heat is obtained from an electric arc, formed between the base metal and an electrode, or between two electrodes.

Arc Welding: A non-pressure (fusion) welding process wherein the heat is obtained from an electric arc formed either between the base metal and an electrode, or between two electrodes.

Atomic Hydrogen Welding: An alternating current arc welding process wherein the heat is obtained from an arc produced between two suitable electrodes in an atmosphere of hydrogen.

Brazing: A group of welding processes wherein the filler metal is a non-ferrous metal or alloy whose melting point is higher than 1000° F. but is lower than that of the metals or alloys to be joined.

Carbon Arc Welding: An arc welding process wherein a carbon or graphite electrode is used, with or without the use of filler metal.

Carburizing Flame (Carbonizing): A gas welding flame having carbonaceous fuel gas in excess of that required to produce a neutral flame.

Chemical Dip Brazing: A dip brazing process wherein the filler metal is added to the joint before immersion in a bath of molten chemicals.

Dip Brazing: A group of brazing processes wherein the heat is obtained from a bath of molten metal or

* Prepared by the Nomenclature, Definitions and Symbols Committee of the A. W. S. and approved by the Executive Committee of the A.W.S.

chemical and the filler metal may or may not be obtained from the bath.

Direct Current Arc Welding: An arc welding process wherein the power supply at the arc is direct current.

Electric Brazing: A group of brazing processes wherein the heat is obtained from an electric current.

Flash Butt Welding: A resistance butt welding process wherein the potential is applied before the parts are brought in contact and where the heat is derived principally from a series of arcs between the parts being welded.

Forge Welding (Blacksmith, Roll, Hammer): A group of pressure welding processes wherein the parts to be welded are brought to suitable temperature in a furnace and the weld is consummated by pressure or blows.

Furnace Brazing: A brazing process wherein the heat is obtained from a furnace in which the atmosphere may or may not be controlled.

Gas Brazing: A brazing process wherein the heat is obtained from a gas flame.

Gas Welding: A non-pressure (fusion) welding process wherein the heat is obtained from a gas flame.

Induction Brazing: An electric brazing process wherein the heat is obtained from induced current.

Metal Arc Welding: An arc welding process wherein the electrode supplies the filler metal in the weld.

Metal Dip Brazing: A dip brazing process wherein the filler metal is obtained from the molten metal bath.

Neutral Flame: A gas welding flame wherein perfect combustion prevails.

Non-Pressure (Fusion) Welding: A group of welding processes wherein the weld is made without pressure.

Oxidizing Flame: A gas welding flame having oxygen in excess of that required to produce perfect combustion. See "Neutral Flame."

Oxyacetylene Welding: A gas welding process wherein the heat is obtained from the combustion of oxygen and acetylene.

Oxy-Other Fuel Gas Welding: A gas welding process wherein the welding heat is obtained from the combustion of oxygen and any other fuel gas not listed herein.

Pressure Thermit Welding: See "Thermit (Pressure) Welding."

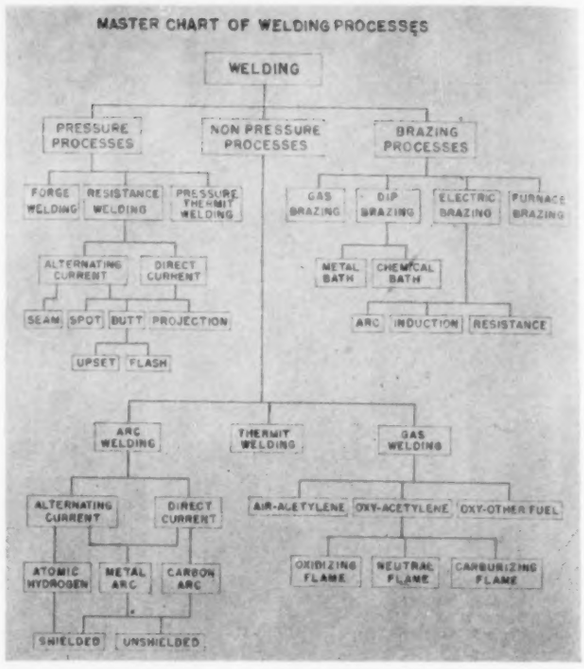
Pressure Welding: A group of welding processes wherein the weld is consummated by pressure.

Projection Welding: A resistance welding process wherein localization of heat between two surfaces or between the end of one member and surface of another is effected by projections.

Resistance Brazing: An electric brazing process wherein the heat is obtained from the resistance to the flow of an electric current.

Resistance Butt Welding: A group of resistance welding processes wherein the fusion occurs over the entire cross sectional area.

Resistance Welding: A pressure welding process wherein the heat is obtained from the resistance to the flow of an electric current.



Seam Welding: A resistance welding process wherein overlapping or tangent spot welds are made progressively.

Shielded Carbon Arc Welding: A carbon arc welding process wherein the welding arc and/or weld metal is protected from the atmosphere by a shielding medium.

Shielded Metal Arc Welding: A metal arc welding process wherein the arc and/or weld metal is protected from the atmosphere by a shielding medium.

Spot Welding: A resistance welding process wherein the heat is confined to a relatively small portion of the area of the parts to be joined.

Thermit Welding: A non-pressure (fusion) welding process wherein the heat is obtained from liquid steel produced by a thermit reaction, and the filler metal is supplied by the steel produced in this reaction.

Thermit (Pressure) Welding: A pressure welding process wherein the heat is obtained from liquid products of a thermit reaction.

Upset Butt Welding: A resistance butt welding process wherein the potential is applied after the parts to be welded are brought in contact and where the heat is derived principally from resistance.

Unshielded Carbon Arc Welding: A carbon arc welding process wherein no shielding medium is used.

Unshielded Metal Arc Welding: A metal arc welding process wherein the electrode used is a bare of lightly coated wire or rod.

Weld: A localized consolidation of metals.

BOUND VOLUME JOURNAL

The AMERICAN WELDING SOCIETY has made arrangements for members who wish to have their Journals for 1937 bound in attractive, imitation black leather covers, to do so by sending copies of the twelve issues to Russell-Rutier Company, Thirty-Third Street and Eighth Avenue, New York, N. Y., Att. Mr. Russell Lauben, Jr. A special reduced rate has been arranged at $1.75 per volume providing the issues of the JOURNAL are sent to the binder on or before February 10th. The bill for the binding and return postage will be sent direct from the Society's office.

CUTTING AND TEMPERING OF Structural Steels*

By H. H. MOSS†

THERE are few ferrous metals which do not respond readily to flame cutting and most of them, particularly those commonly used for structural purposes, contain sufficient combustible matter to permit of straight line progressive applications of the cutting flame. This is the common method with which we are all more or less familiar.

From a purely cutting standpoint this facility provides a simple and economical production tool for shaping steel. On the other hand, all grades of steel do not react the same way physically in going through the cutting process, taking on properties in the cut surfaces differing from those initially present in the steel. This is more or less true also of mechanical severing and shaping operations such as sawing, planing and shearing, and is a matter which must be appraised before cutting, first to determine whether the altered properties fall within the required specifications governing the objective of the steel in question, and if they do not, secondly, to provide means for either avoiding the trouble or removing the undesired properties.

The behavior of steel in this respect and certain remedial procedures, therefore, from a flame cutting standpoint, have been discussed before this Association on many occasions, and we are reminded particularly of the recommendations of Mr. L. M. Curtis made before our 32nd Annual Convention at Chicago. In his paper—"Machine Gas Cutting Heavy Plate," he pointed out that the physical and chemical changes produced by the cutting operation leave a thin hardened zone on the outside edge, the penetration of which is usually superficial, and that with ordinary steels of 0.30% carbon and under, no particular difficulty is experienced in bending or fabricating as the sorbitic hardening is not intense, whereas with high carbon and alloy steels, the precautions of annealing or machining should be used to remove the hardened edge.

The line of demarcation in applied flame cutting where real damage begins to take place for the various grades of steel now on the market has not been accurately or fully determined to the author's knowledge, nor can it be gaged by a single yardstick. From the structural standpoint, it is required that the flame-cut metal satisfactorily pass the standard tests prescribed for the parent metal. This calls for liberal ductility and the retention of other properties within specified limits. However, in other cases, it may be required only that the flame-cut metal be machinable. Where the part is to be subjected to furnace treatment soon after cutting, and the rigidity of the part is such that handling operations do not induce important flexural stresses in the cut surfaces, it may only

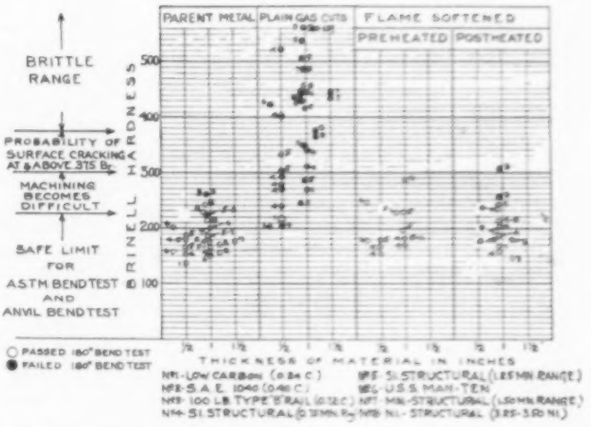


Fig. 1—A Graphic Presentation of the Hardness Data for Eight of the Steels Listed in Table No. 1

be required that the flame-cut metal be sufficiently ductile to prevent microscopic or visible surface checking or cracking during cooling following cutting. For the plain carbon structural steel of normal manganese content, such as A-7 and A-9 grades, the line of demarcation under standard A. S. T. M specifications seems to run between 0.30 to 0.35% carbon above 32° F.

Several of the so-called low-alloy high strength structural steels go through the process of flame cutting quite satisfactorily at normal temperatures, such as the low manganese silicon structural steels in gages not exceeding $^5/_8$ inch providing the carbon content is likewise on the low side. The low-carbon chrome-phos steels and other steels in this class employing small amounts of nickel and molybdenum in the lighter gages are not seriously affected by flame cutting.

A fairly good picture of the effect of flame cutting on the physical properties of metal in and marginally below the cut surfaces in a number of popular grades of carbon and low-alloy steels may be obtained from Table No. 1. The data for this table rest upon average production workmanship for machine flame cutting.

Due to the highly marginal depth of the zone affected by the flame cutting operation, being of the order of $^1/_{32}$ to $^3/_{32}$ inch below the surface for machine cutting, the comparison of physical properties as between uncut and cut metal has necessarily been made on the basis of superficial tests. The comparisons are expressed in terms of hardness and bendability of the metal in the affected zones. Microscopic examinations were also made. The findings are reported in detail elsewhere in this paper.

Unfortunately, there have not been opportunities to perform the cutting tests over the complete range of tempertures in which steels are commonly fabricated. The tests being conducted at the normal temperatures of the

* Presented at Joint Meeting New York Section, A. W. S. & Metropolitan Section, A. S. C. E., Nov. 17, 1937. Read at the 38th Annual Convention, International Acetylene Association, Birmingham, Alabama, November 10, 11 and 12, 1937.

† Development Engineer, The Linde Air Products Company.

TABLE NO. 1—

PROPERTIES OF PLAIN GAS-CUT AND FLAME-SOFTENED GAS CUT SU

GROUP AND GRADE	AVERAGE CHEMICAL ANALYSIS									AVERAGE PHYSICAL PROPERTIES OF PARENT			
	Analysis	C	Mn	Si	P	S	Cu	Ni	Cr	Thickness in Inches	Yield Pt. # p.s.i.	Ult. Tens. # p.s.i.	% Elongation 2" 8"
A. *Carbon Steels*													
Low Carbon[1]	L.A.	0.24	0.46	0.10	0.017	0.033				1/2	35,700	61,400	30
SAE #1040	M.A.	0.40	0.57	0.10	0.02	0.04				1-3/8	52,000[4]	85,000[4]	26[4]
High Carbon	M.A.	0.70	0.77	0.24	0.033	0.032				4-1/8	(None reported)		
100# Rail	—	(None reported)—(.70 C. assumed)								9/16 at cut	(None reported)		
100# ARA Type B Rail	L.A.	0.72	0.73							7/8 " "	(None reported)		
B. *Silicon*													
Low Mn. Structural[11]	M.A.	0.28	0.71	0.21						1/2 & 1-1/16	(None reported)[13]		
" [11]	M.A.	0.28	0.675LA	0.21						1/2	(None reported)[13]		
" [11]	M.A.	0.28	0.685LA	0.21						1-1/16	(None reported)[13]		
"	M.A.	0.28	0.71	0.21						1	(None reported)		
"	L.A.	0.30	0.73	0.26						1-1/16	(None reported)		
"	L.A.	0.31	0.73	0.25						1/2	(None reported)		
"	M.A.	0.33	0.73	0.276	0.018	0.035	0.21			7/8	49,800	85,525	23.4
"	L.A.	0.36	0.70	0.23						7/8	(None reported)		
"	M.A.	0.38	0.86	0.312	0.021	0.034				7/8	50,340	92,990	21.0
Med. Mn. Structural	L.A.	0.26	1.28	0.22						1/2	(None reported)		
" [12]	M.A.	0.26	1.23	0.23	0.019	0.024				1/2	54,900	87,890	21
" [12]	M.A.	0.273	1.22[6]	0.25	0.020	0.026				7/8 & 15/16	50,515	88,140	20.45
" [12]	M.A.	0.29	1.23[7]	0.247	0.028	0.033				5/8 & 3/4	58,720	88,120	22.7
C. *Manganese*													
Abrasive Resistance	M.A.	0.39	1.30	0.18	0.02	0.04				5/8	(None reported)		
U.S.S. Man-Ten	M.A.	0.30	1.43	0.216	0.030	0.034				1/4	59,300	90,640	37 21
Structural	M.A.	0.33	1.43	0.196	0.028	0.027				7/8	68,040	97,700	18.3
U.S.S. Man-Ten	M.A.	0.29	1.55	0.252	0.022	0.025				1	60,350	89,500	40. 23.7
Structural	L.A.	0.27	1.61	0.13						1-1/2	58,600[8]	101,600[8]	19.5[9]
D. *Silico-Manganese*	M.A.	0.40	1.51	2.00	0.018	0.028				3-1/16	(None reported)		
E. *Nickel*													
Structural	M.A.	0.29	0.66	0.124	0.037	0.020		3.32		7/8	64,150	99,420	16.7
"	M.A.	0.31	0.66		0.017	0.025		3.39		3/4	(None reported)		
"	M.A.	0.33	0.71		0.025	0.025	0.26	3.21		3/4	64,370	104,150	18.0
F. *Chrome-Nickel*	M.A.	0.28	0.23	0.076	0.014	0.021		3.29	1.29	2	(None reported)		
G. *U.S.S. Cor-Ten*	M.A.	0.07	0.15	0.72	0.12	0.018	0.44		0.70	1/4	56,380	71,960	49 30
	M.A.	0.10	0.20	0.728	0.131	0.021	0.41		0.88	1	50,420	74,100	45 26.2

M.A. = Mill Analysis

L.A. = Lab. Analysis (UC&C Res. Labs)

C.B. = Cold bend in degrees of bend

F.B. = Free bend in % elongation

A.B. = Anvil bend in degrees of bend

pre. = Simultaneously preheated—Type I treatment

post = Simultaneously postheated—Type I treatment

I.P. = Independent postheat—Type III treatment

NOTES:

(1) Properties reported by J. H. Zimmerman: "A Comparative Study of Cutting Methods as Applied to Structural Steel." I.A.A. Proceedings for 1934.

(2) Direction of rolling: longitudinal.

(3) Direction of rolling: transverse.

(4) Nominal for natural hot rolled plate.

(5) Hardness effected by annealing action of preheating flames of the cutting nozzle.

(6) Lab. analysis: 7/8"—1.09% Mn., 15/16"—1.13% Mn.

(7) Lab. analysis: 3/4"—1.185% Mn.

laboratories and fabricating shops where this work was carried out, with one or two exceptions as noted in the paper, increased hardening can be expected when the steels are cut at lower temperatures and vice versa.

In the column of Table 1 headed "Plain Gas-Cuts" it will be seen that as the nominal strength of the steels increases, the hardness of the gas-cut surface increases somewhat correspondingly, however, in a higher order of hardness. Plain carbon steel, on the low carbon side, is seen to pass through the cutting process satisfactorily. The degree of hardening has not been sufficient to prevent a satisfactory cold bend. Reference is here made to the

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CUT SURFACES IN SOME CARBON AND LOW ALLOY STEELS

OF PARENT METAL		PROPERTIES OF MACHINE GAS-CUT SURFACES				
		PLAIN GAS-CUTS		FLAME-SOFTENED GAS-CUTS		
Bend Test	Hardness in Terms of Standard Brinell	Hardness in Terms of Standard Brinell	Bend Test	Hardness in Terms of Standard Brinell	Anvil Bend Test Deg. of Bend	Temp. Material When Cut
180°	137 (ave. 1/2" below machined edge) 165 (ave. machined surface)	218 (max.)	180° C.B.(2) 170°-180° C.B.(3)			Approx. 70° F.
180°(4)	153 low—170 high 179 (ave. furnace annealed) 241 (ave.)	364 low—375 high 532 (ave.) 585 (ave.)		146 low—179 high (post) 235 (ave.) (I.P.) 241 (ave.) (post)(14)		Approx. 50° F. Bet. 70°-80° F. Approx. 45° F.
34°—43° A.B.	222 low—259 high	583 low—639 high	0—Abrupt	254 low—325 high (post) (14) (15) 304 low—308 high (post) (14) (15) 255 low—280 high (post) (14) (15)	3° 33° 62°	
56° in 1/2" F.B.	159 low—168 high	291 low—402 high	8° in 1/2" F.B.			
O.K. C.B.	153 low—179 high	202 (ave.)	164° C.B.	153 low—166 high (pre.)	180°	Approx. 70° F.
O.K. C.B.	149 low—159 high	187 low—192 high	180° C.B.	170 low—179 high (pre.)	180°	Approx. 70° F.
40° in 1/2" F.B.	156 low—174 high	310 low—341 high	10° in 1/2" F.B.			Approx. 70° F.
	153 (ave.)	192 low—248 high				Approx. 70° F.
	159 (ave.)	202 low—248 high				Approx. 70° F.
180° C.B.	171 (ave.)	269 low—409 high	17° to 38° A.B.	156 low—203 high (post)	180°	
180° C.B.	163 (ave.)	238 low—241 high	38° C.B.			
180° C.B.	175.5 (ave.)	277 low—522 high	10° to 15° A.B.	188 low—212 high (post)	180°	
	179 (ave.)	255 (ave.) (5)				
180° C.B.	165 low—183 high	302 low—332 high	0—Abrupt C.B.	179 (ave.) (pre.)	OK—C.B.	Approx. 70° F.
180° C.B.	166 low—183 high	286 low—418 high	0 to 56° C.B.	179 low—228 high (pre.)	OK—C.B.	Approx. 70° F.
180° C.B.	174 low—223 high	241 low—444 high	0 to 25° C.B.	199 low—228 high (pre.)	OK—C.B.	Approx. 70° F.
	166 low—179 high	460 low—555 high	0—Abrupt A.B.	179 (ave.) (post)	180°	Approx. 50° F.
180° A.B.	156 low—200 high	203 low—421 high	42°—132° A.B.	179 low—245 high (pre.)	180°	
180° A.B.	181 low—196 high	344 low—486 high	7°—32° A.B.	166 low—241 high (post)	180°	
180° A.B.	150 low—200 high	269 low—444 high	20°—72° A.B.	179 low—285 high (pre.)	180°	
38° to 46° F.B.	174 (ave.)	435 low—444 high	8° in 1/2" F.B.	(Hardness data	180°	
55° to 70° C.B.			11° to 15° C.B.	missing) (pre.)		
	140 (ave. furnace annealed)	469 (ave.)		241 (ave.) (I.P.)	Not subjected	Bet. 70°-80° F.
180° A.B.	226 low—240 high	430 low—504 high	9°—20° A.B.	196 low—237 high (post)	180°	
180° A.B.		437 low—486 high		179 (ave.)(9) (post)	180°	
180° A.B.	214 low—219 high	462 low—539 high	5°—44° A.B.	195 low—212 high (post)	180°	
	196 (ave. furnace annealed)	455 (ave.)		262 (ave.) (I.P.)		Bet. 70°-80° F.
180° A.B.	132 low—168 high	132 low—203 high	180° A.B.			
180° A.B.	134 low—175 high	150 low—258 high	94°-180° A.B.(10)	145 low—200 high (pre.)	180°	

(8) These values quoted from Table 22, "Evolution of High Strength Steels Used in Structural Engineering," by L. S. Moisseiff, Oct., 1936, A.S.C.E. Symposium, "Structural Applications of Steel and Light Weight Alloys."

(9) This figure is unusually low for the grade of steel in question; however, the hardness of flame-softened cuts in this grade is consistently below the hardness of as-rolled condition.

(10) Cor-Ten in gauges 3/4" and 1" will pass 180° AB test satisfactorily if cut at reduced cutting speeds. For fast production cuts, a mild softening treatment is necessary for the same degree of ductility.

(11) From Trans-Bay Bridge heats.

(12) From Golden Gate Bridge heats.

(13) Average properties reported by V. D. Beard in paper: "Actual Applications of Special Structural Steels," presented before A.S.C.E. Symposium, Pittsburgh, Oct. 14-15, 1936, Page 1255, as follows: Carbon 0.31%, Manganese 0.82%, Yield Point 53.9 kips/sq. in., Tens. 89.8 kips/sq. in., elongation in 2"—22.8%.

(14) Type II treatment.

(15) These results were obtained with varying heat treatments.

Note: Due to the shallow depth of the hardened zone under investigation in these tests, hardness readings were made with the Rockwell "C" scale for the hardest surfaces and with the Rockwell "B" scale for flame-softened surfaces. In the field, in some cases, the portable scleroscope was used. All readings have been converted to standard Brinell according to the T. N. Holden Chart (Iron Age, July 10, 1930, Page 80).

work of Prof. J. H. Zimmerman on "Plain Low-Carbon Steel" at the Massachusetts Institute of Technology, 1934 and 1935, reported to this Association at its 35th and 36th Annual Conventions from which the data for the low-carbon steels was obtained.

Similar credit can be given to some of the grades in Groups *B* and *G*. The degree of hardening is seen to range from that amenable to bending as prescribed by applicable standard specifications to a very hard stage characterized by extreme brittleness. The relationship in this respect is shown graphically on the left-hand side of Fig. 1 for eight grades of steel listed in Table No. 1.

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GROUP AND GRADE	AVERAGE CHEMICAL ANALYSIS									AVERAGE PHYSICAL PROPERTIES				OF PARA	
	Analysis	C	Mn	Si	P	S	Cu	Ni	Cr	Thickness in Inches	Yield Pt. # p.s.i.	Ult. Tens. # p.s.i.	% Elongation 2" 8"		Bend Test
A. *Carbon Steels*															
Low Carbon[1]	L.A.	0.24	0.46	0.10	0.017	0.033				1/2	35,700	61,400	30		180°
SAE #1040	M.A.	0.40	0.57	0.10	0.02	0.04				1-3/8	52,000[4]	85,000[4]	26 [4]		180° [4]
High Carbon	M.A.	0.70	0.77	0.24	0.033	0.032				4-1/8	(None reported)				
100# Rail	—	(None reported)—(.70 C. assumed)								9/16 at cut	(None reported)				
100# ARA Type B Rail	L.A.	0.72	0.73												
B. *Silicon*															
Low Mn. Structural[11]	M.A.	0.28	0.71	0.21											
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" [11]	M.A.	0.28	0.685LA	0.21											
"	M.A.	0.28	0.71	0.21											
"	L.A.	0.30	0.73	0.26											
"	L.A.	0.31	0.73	0.25											
"	M.A.	0.33	0.73	0.276	0.018	0									
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	M.A.	0.10	0.20	0.728	0.131	0.021	0.41		0.88	1	50,420	74,100	45	26.2	180° A

TIGH
BOU

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180°(4)	153 low—170 high 179 (ave. furnace annealed)	364 low—375 high 532 (ave.)		146 low—179 high (post) 235 (ave.) (I.P.) (ave.) (post)(14)		Approx. 50° F. Bet. 70°-80° F. Approx. 45° F.
				low—325 high (post) (14) (15) low—308 high (post) (14) (15) low—280 high (post) (14) (15)	3° 33° 62°	
				low—166 high (pre.) low—179 high (pre.)	180° 180°	Approx. 70° F. Approx. 70° F. Approx. 70° F. Approx. 70° F. Approx. 70° F.
				low—203 high (post) low—212 high (post)	180° 180°	
				(ave.) (pre.) low—228 high (pre.) low—228 high (pre.)	OK—C.B. OK—C.B. OK—C.B.	Approx. 70° F. Approx. 70° F. Approx. 70° F.
				(ave.) (post) low—245 high (pre.) low—241 high (post) low—285 high (pre.) dness data ssing) (pre.)	180° 180° 180° 180° 180°	Approx. 50° F.
				(ave.) (I.P.)	Not subjected	Bet. 70°-80° F.
				ow—237 high (post) (ave.)(9) (post) low—212 high (post)	180° 180° 180°	
	196 (ave. furnace annealed)	455 (ave.)		262 (ave.) (I.P.)		Bet. 70°-80° F.
180° A.B. 180° A.B.	132 low—168 high 134 low—175 high	132 low—203 high 150 low—258 high	180° A.B. 94°-180° A.B.(10)	145 low—200 high (pre.)	180°	

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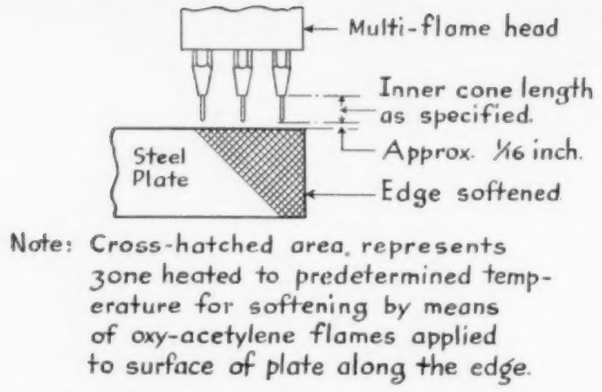

Multi-flame head
Inner cone length as specified.
Approx. 1/16 inch.
Steel Plate
Edge softened
Note: Cross-hatched area represents zone heated to predetermined temperature for softening by means of oxy-acetylene flames applied to surface of plate along the edge.

Fig. 2a—Sketch Illustrating the Set-Up for Type No. I Flame-Softening Treatment

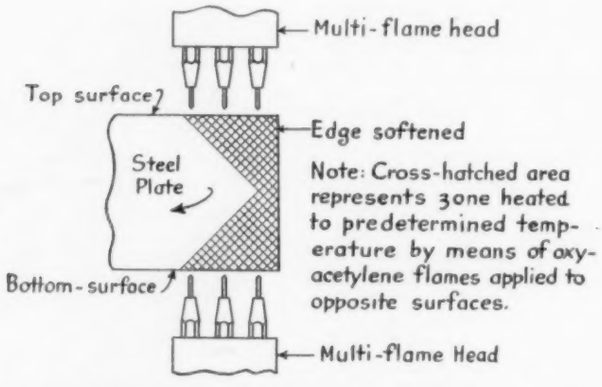

Multi-flame head
Top surface
Edge softened
Steel Plate
Note: Cross-hatched area represents zone heated to predetermined temperature by means of oxy-acetylene flames applied to opposite surfaces.
Bottom-surface
Multi-flame Head

Fig. 2b—Sketch Illustrating he Set-Up for Type No. II Flame-Softening Treatment

The plotted data regard the range of hardness for each steel according to the classifications at the top of the diagram and using 180° bend test either in the form of the standard cold bend test or the hammer bend test, later described in this report, as criterion for emphasizing the critical hardening. The solid circles represent surfaces which failed to pass the 180° bend test, those of the lower order of hardness enjoying a considerable degree of ductility nevertheless, while on the other hand, those in the upper hardness range have extremely brittle characteristics.

The figure regards four stages of hardness, the limits of which, though more or less arbitrarily determined, rest upon the findings of many tests and observations. The limits of the upper stages are more approximate than those of the lower stages.

The low alloy structural grades of steel, with few exceptions, are seen to be in an extremely vulnerable position in the chart which explains why it has been necessary for the fabricating shops to machine or grind cut surfaces in these grades in order to prevent subsequent damage to these surfaces either in shop handling, assembly, erection or while in service.

Where the dimensions of the parts permit, resort has been made in some cases to furnace preheating and annealing after cutting to prevent and/or overcome hardening, or, as is often done in the steel mills, to sandwich the parts to be cut between hot slabs or ingots to give them sufficient body heat to prevent quenching of the cut edges. Similar remedial practices are employed for the plain high carbon steels and the more prominent high-alloy grades which are readily cuttable.

These supplementary operations, while effective in purpose where they can be applied, add substantial increments of cost to flame cutting operations. There are cases also where, due either to the size of the part to be cut or to the contour of the cut, such supplementary operations are not feasible. These conditions influence and often lead to adoption of other means for shaping and preparation, even though being more costly, and in some instances, they lead to restrictions in the use of an otherwise desirable steel.

As an example, it was found to be more economical at one point, where smooth edges were required, to shear and plane straight-line cuts for gusset plates up to the capacity of the shear than to flame-cut and attempt to plane the hardened edges. In another case it proved to be more practical to drill with supplementary grinding or chipping to produce openings in web plates than to heat the plates, flame-cut the openings and anneal after cutting.

General shape cutting of the hard structural steels is practically out of the question unless large capacity heat treating furnaces are provided, as subsequent machining is usually prohibitive in cost.

A simple and economical solution of this problem was the objective of a development program undertaken by the author's company about the time when construction work was getting under way for the Golden Gate and Trans-Bay bridges at San Francisco. This program was stimulated by an adverse report on flame cutting of silicon structural steel obtained from heats providing material for the former structure, submitted by Mr. Leon S. Moisseiff, Consulting Engineer of New York, before the Structural Steel Welding Committee under the former American Bureau of Welding at its Spring meeting in 1933. The trouble was investigated and the results led to the conclusion that flame cutting, as ordinarily applied, was not a satisfactory tool for the grade of steel in question and was so stated to the Committee.

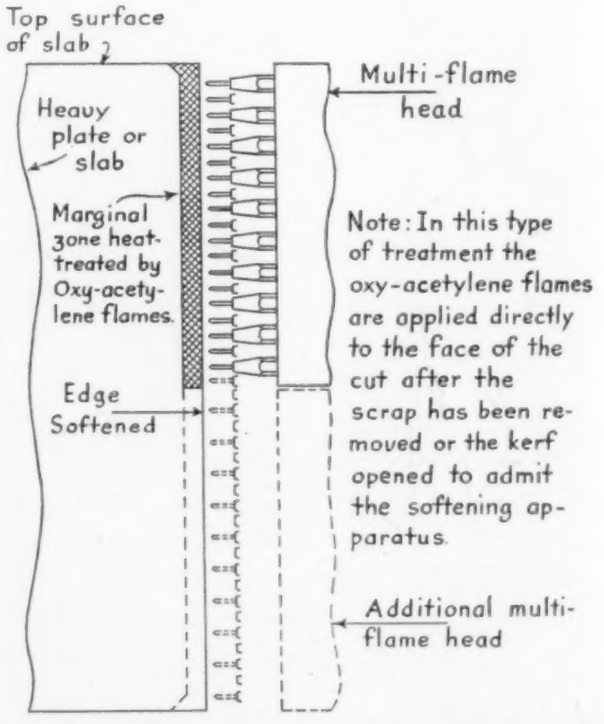

Top surface of slab
Heavy plate or slab
Marginal zone heat-treated by Oxy-acetylene flames.
Edge Softened
Multi-flame head
Note: In this type of treatment the oxy-acetylene flames are applied directly to the face of the cut after the scrap has been removed or the kerf opened to admit the softening apparatus.
Additional multi-flame head

Fig. 2c—Sketch Illustrating the Set-Up for Type No. III Flame-Softening Treatment

Localized heat treating provided a means for overcoming the trouble, and its coordination with cutting effected an economical solution. Means were found to carry out the heat treating operation simultaneously with cutting for the usual thicknesses of steel employed in general construction work, thus simplifying the operation still further.

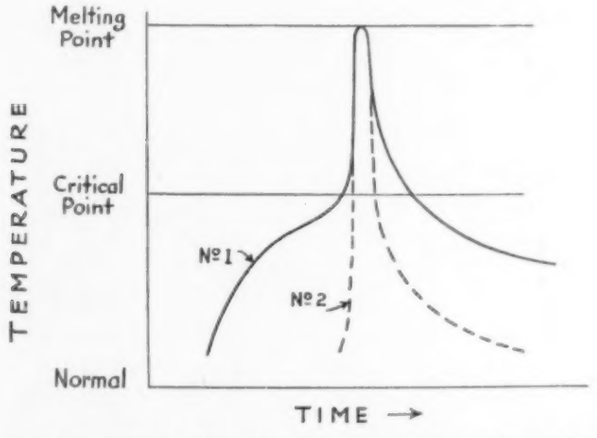
Rapid heat flow with a suitable quantity of heat was necessary for the latter facility, in turn, calling for a steep temperature gradient between the source of heat and the relatively cold plate. The oxyacetylene flame provided this, and the necessary quantity of heat was obtained by banking numerous flames in suitable blocks which could be manipulated about the cutting zone to effect the desired heat treatments. Simultaneous operation of the heat treatment with cutting from this point required only the adjustment of heat quantity to effect a specific treatment at a specified cutting rate.

As the gage of the metal increases, it becomes more and more difficult and expensive to carry out the simultaneous operation inasmuch as it must be performed by soaking the heat into the metal from its nominal surfaces due to inaccessibility of the walls of the cut during the cutting operation which are confined within a narrow slot or kerf before the respective parts are separated. For the heavy gages therefore, it was found to be more practical to apply the localized heat treatment directly onto the surface of the cut after the parts were separated. This operation is likewise performed progressively for long cuts.

The several methods for applying the heat treatment, or "flame-softening" as the process has recently been termed, for all thicknesses, are shown diagrammatically in Fig. 2.

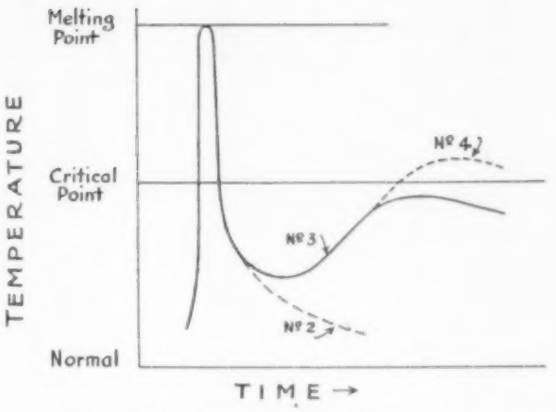
Type No. I treatment, as shown by Fig. 2*a*, has been successfully applied to plate thicknesses up to and including $1^1/_2$ inches where it is desired to meet the requirements for bending laid down by standard specifications. For a lower degree of softening than is required by these specifications, this thickness range for Type I treatment may be extended to 2 inches or even to 3 inches.

Type No. II treatment, as shown in Fig. 2*b*, extends the principle of Type No. I treatment to approach 4 inches, depending upon the grade of steel. However, due to mechanical difficulties in underreaching a plate, this type treatment is more or less confined to edge cutting or where the cut can be conveniently reached by relatively short extension arms from along the edge of the material.



Curve №1-Type №1 Treatment, Preheating plus Cutting
Curve №2-Plain Flame Cutting

Fig. 3—Time-Temperature Curve for Simultaneous Preheating



Curve №2-Plain Flame Cutting.
Curve №3-Type №1 Treatment, Postheat below Critical.
Curve №4-Type №1 Treatment, Postheating above Critical.

Fig. 4—Time-Temperature Curve for Simultaneous Postheating

This type of treatment was found advantageous in making guard rails from standard railroad rails for a case where it was necessary to reduce the width of one flange of the rail. The under flames in this case operated to offset the additional chill induced into the flange by the web of the rail, enabling the treatment to proceed at a faster rate than would otherwise have been practicable for Type No. I treatment.

Type No. III treatment, as shown in Fig. 2*c*, comes into play for the heavy gages. It should preferably be applied before the cut surfaces cool to room temperature, particularly in the case of those grades which are extremely sensitive in order to prevent microscopic and/or visible surface checking or definite cracking.

Within the scope of heat treating as carried out under the premises above described, the grades of steel softened to date may be arranged into two groups:

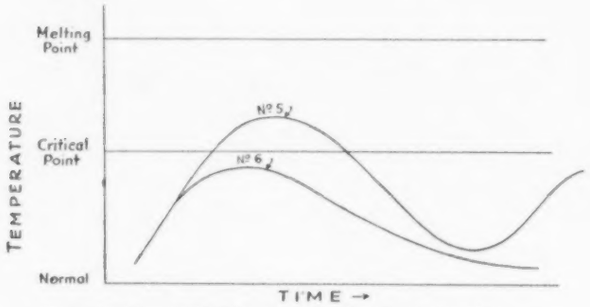
The first group includes those which harden only when rapidly quenched from temperatures above the critical point which classify under flame softening terminology as "quench hardening steels." This group includes the plain carbon steels of medium carbon content, the structural steels of low-carbon and low-manganese content and some of the newer corrosive resisting low-alloy steels beforementioned. The second group, which classifies as "air hardening steels," includes those which harden when slowly cooled in shop atmospheres from temperatures above the critical point, such as the low-alloy high strength structural steels.

The approximate characteristics of the several flame-softening treatments from the time-temperature standpoint are shown graphically in Figs. 3, 4 and 5.

Figure 3 indicates the approximate slope of the time-temperature curve for preheating to a visible red color in shop daylight simultaneously with cutting. It is seen that the effect of preheating has been to raise the temperature of the steel at the moment of cutting to a point just below the Ac_1 point. If desired, the preheated portion of the curve may be carried above this point for quench hardening steels; however, it is seldom desirable or necessary to do this.

The contrast of curve No. 1 to that of curve No. 2 of Fig. 3 is one giving longer time for the parent metal to cool, which in turn allows more time for the development of soft structures. Here, flame softening prevents hardening by preventing a rapid quench following cutting and is applicable to the so-called quench hardening grades, or,

as previously stated, to those grades which harden only when cooled rapidly from a high temperature to normal temperature.



Curve №5 Type №3 Treatment, Annealing plus Tempering
Curve №6 Type №3 Treatment, Tempering

Fig. 5—Time-Temperature Curve for Type No. III Flame-Softening Treatment

Figure 4 indicates the approximate slope of the time-temperature curve for postheating to a visible red color following cutting. This, like the application shown in Fig. 3, is a Type No. I treatment. Where postheating is employed the heat generated by the cutting operation elevates the temperature of the metal in the cut surface to the melting point, whereupon it drops rapidly passing through the Ac_1 temperature at a rapid rate to a point well below it where it is again elevated by the postheating to a predetermined red heat, from which point it is allowed to cool to normal temperatures.

For air hardening grades requiring this type of heat treatment such as the nickel and silicon and manganese structural steels, it is essential that the postheat not exceed the critical point. The heat treatment effected by curve No. 3 allows the hard constituents to form, whereupon they are tempered or softened by the subsequent heating operation. The treatment depicted by curve No. 3 is also effective for softening the quench hardening grades in which case the postheating may be carried to above the critical point of the steel if desired in order to increase the rate of heating. However this leads to the danger of surface melting, if not carefully performed.

Figure 5 indicates types of time-temperature curves that come into play with Type No. III treatment where the cutting and heat treatment are carried on as separate operations because of the necessity of either dropping the scrap or opening the kerf at the completion of cutting to provide room for the admission of the flame-softening apparatus.

For tempering the constituents residing in the cut surface, curve No. 6 applies, and is similar in its effect to that of curve No. 3 of Fig. 4. If applied immediately after cutting when the cut surface is still hot, which is desirable from several angles, the heat input is consequently less. For steels which are more highly resistant to tempering, such as some of the low-alloy chrome-nickel and chrome-molybdenum steels, the time-temperature conditions for effective tempering are so close to the critical point that it is more expedient to use a different type of treatment than that shown in curve No. 6. An anneal, followed by a sub-critical, in such manner as to increase the time element of tempering has been found effective in producing substantial reductions in the hardness of plain gas-cut surfaces Curve No. 5 approximates the time-temperature conditions for a treatment of this character.

For the majority of steels sensitive to the quenching action following gas cutting, a softening treatment, indicated by curve No. 3 of Fig. 4 for the lower gages and curve No. 6 of Fig. 5 for the heavy gages which employ postheating, serve for both air and quench hardening grades, and therefore require a common set-up of the heat treating apparatus.

Fig. 7—Assembly of Hand-Operated Flame-Softening Blowpipe with 7-Flame Head

In the foregoing diagrams, the critical point is the Ac_1 point in all cases.

The commercial apparatus developed to perform these treatments is shown in Figs. 6 to 12 inclusive. The several units are assembled from standard equipment with the exception of the special brackets or arms for multiple blowpipe mountings which, when needed, are best worked out at the place of application.

Certain aspects of the processes of flame-softening described in this paper are covered by patents and patents pending; however the processes, as presented, are to be made available to the fabricating industry through reasonable license agreements.

Flame-softening heat is provided by either 7-flame or 30-flame water-cooled heads and these are connected by straight or angular fittings to blowpipes providing adequate volumes of mixed gases.

For straight-line mechanical applications for usual fabricating shop purposes, a variable speed, portable propelling unit is employed to move the apparatus over the work. For simultaneous operations of cutting and softening, the flame-softening equipment is merely added to standard mechanical cutting units by means of auxiliary brackets or fixtures. Various combinations of flame assemblies and heat area dimensions can be obtained by grouping the 7-flame and/or 30-flame heads, and by the further expedient of blanking out one or more tips with plugs. When it is desired to soften one side or face of a cut or kerf by postheating, one 30-flame head usually suffices where the thickness of the metal does not exceed $1^1/_2$ to 2 inches. If the cut is through

Fig. 6—Parts for Hand-Operated Flame-Softening Blowpipe with 7-Flame Head

the body of the plate and it is desired to soften both sides or faces of the cut, two 30-flame heads should be used, one operating on either side of the kerf.

For Type III treatment in heavy slabs, economy may be obtained by banking two or more heads abreast. For small cuts and those inaccessible to mechanical equipment, the 7-flame hand blowpipe has been found most useful.

Figure 6 illustrates the parts for the hand type flame-softening unit showing a 7-flame water-cooled head with water inlet and outlet connections, and straight and curved stems for the blowpipe handle.

Figure 7 is an assembly of the hand type blowpipe complete with service connections for oxygen, acetylene and water.

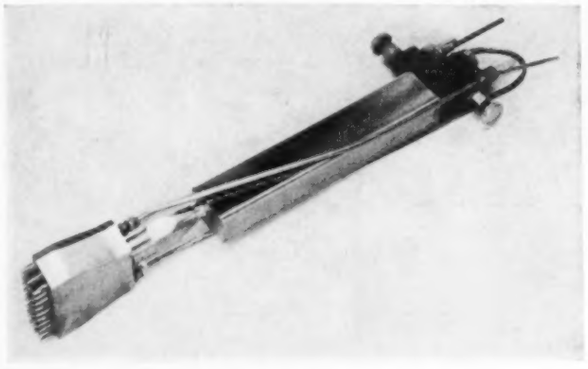


Fig. 8—Flame-Softening Blowpipe with 30-Flame Head

Figure 8 shows an assembly of a 30-flame water-cooled rhomboid head with appropriate water-cooled blowpipe with cooling water tubing.

Figure 9 shows a tandem group of two 30-flame rhomboid heads illustrating a means for increasing the length of the flame softening heat area.

Figure 10 is a front view of standard apparatus for simultaneous Type I treatment using a single bank of 30 flames shown in the operation of cutting and flame softening a 1-inch low-alloy plate. The apparatus is preheating in this case, but could readily be changed to postheating by reversing the direction of travel and moving the 30-flame head sideways so as to direct the flames upon that side of the cut having the surface to be softened.

Figure 11 shows a special assembly of standard apparatus to provide a flame-softening treatment similar to that depicted by Curve No. 5 of Fig. 5. As the steel being treated is less in thickness than the full width of the 30-flame heads, seven of the upper tips have been plugged to keep the flames within the bounds of the surfaces being treated. The first bank of heads heats the surfaces of the steel to an annealing temperature, the intervening space allowing this temperature to drop to a suitable black heat, whereupon the second bank of flames reheats the surface to a temperature under the critical point, thus effecting a temper or draw from below this point.

Figure 12 shows a rear side view of the above apparatus in operation.

The degree of softening produced by flame-softening processes in the grades of steel listed in Table 1 is also shown in that Table under "Properties of Machine Gas-Cut Surfaces," and again in Fig. 1 under the heading "Flame Softened." It is seen that by either preheating or postheating with Types I, II and III treatments, hardness has been prevented or kept within reasonable

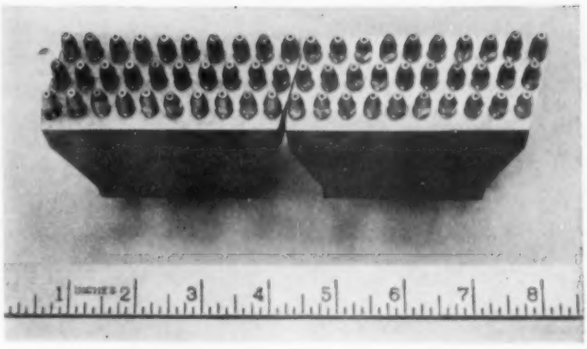


Fig. 9—Tandem Group of Two 30-Flame Heads

limits. For the structural grades in both the quench-hardening and air-hardening groups, the residual ductility in the cut surfaces, after softening, when cooled to normal temperatures, is of the same order as that of the parent metal, having withstood either the standard cold-bend test or the hammer-bend test without cracking. In some cases, the residual hardness is slightly lower than that of the rolled material.

In the case of the critical high-carbon steels in Group "A" and the steels in Groups "D" and "F" which were treated non-simultaneously by the Type III treatment, the hardness of the cut surfaces has been reduced nearly 50% by a single high-speed tempering pass, or to such degree to be readily machinable or to overcome the possibility of cracking during cooling. Modification of this treatment should lower the hardness still further.

Bendability of the unsoftened and softened surfaces was determined in most cases by a hammer-bend test or, as later termed, an "anvil-bend test," which subjected the surface to bending in combination with shock.

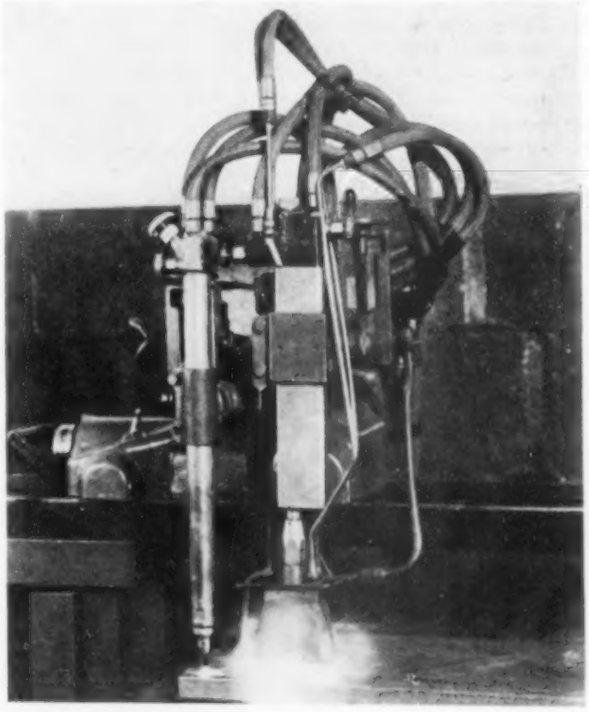


Fig. 10—Standard Apparatus for Type No. I Flame-Softening Treatment Using a 30-Flame Head

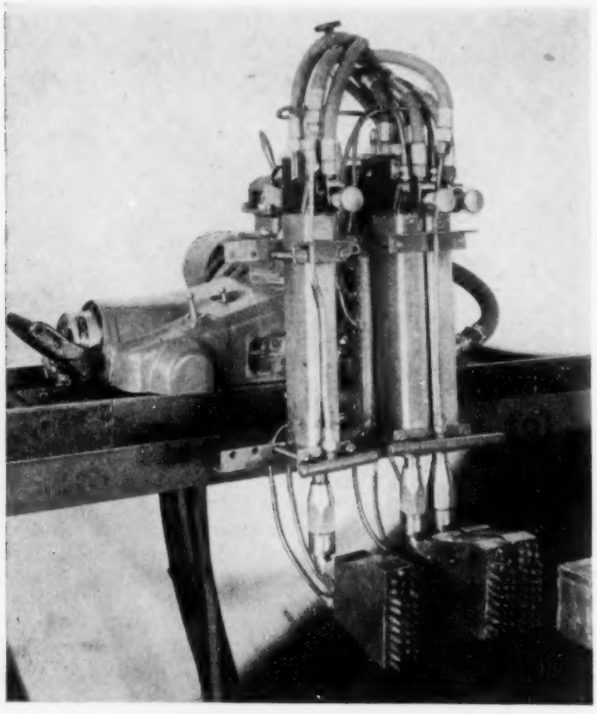


Fig. 11—Standard Apparatus to Provide a Flame-Softening Treatment Depicted by Curve No. 5 in Fig. 5

This was accomplished by hammering the specimens around an anvil as shown in Fig. 13.

The diameter of the nose of the anvil was made equal to twice the thickness of the specimens which, in turn, was made $^1/_2$ inch in all cases for purposes of expediency in determining the relative ductility of the various specimens. The force of the blow applied to effect this test was appreciable, being that developed by the full arm swing of a 6-lb. to 8-lb. sledge hammer. The blows were applied at the extreme outer end of the specimen so as to resolve the force into definite bending and shear stress. The measure of ductility for the surface under test was the angle of the arc attained by the specimen in bending around the anvil at the moment of rupture of the remote fibers at the crown of the bend.

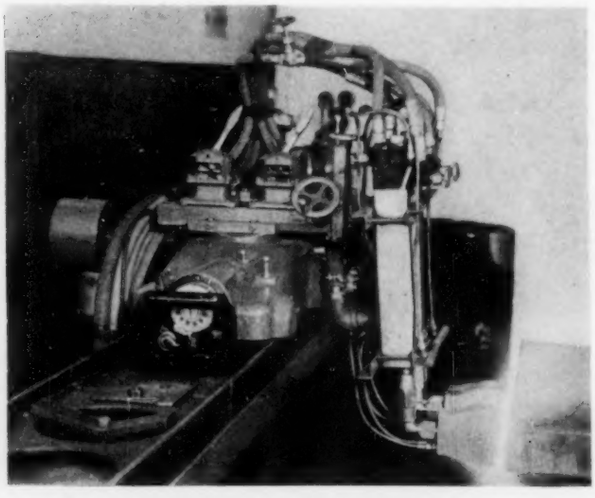


Fig. 12—The Apparatus Illustrated in Fig. 11 in Operation

It is this angle which is quoted in the several bend test tabulations in the body of this report where designated as "anvil bends."

While this test is somewhat at variance with standard pin-bend tests, both as to manner of testing and ratio of pin diameter and thickness of specimen, it is regarded as a more drastic test of metal surfaces, particularly of the marginally affected zones under the cut surface, than the slowly applied standard pin-bend tests.

The factor of impact introduced in the anvil-bend test subjected the metal under investigation to shock, in combination with an appreciable amount of flexural stresses, a condition often encountered in commerce, particularly in some bridges, railroad vehicles and numerous pieces of industrial equipment.

The amount which a specimen bends depends to a large extent upon the character of its outer surface. If smooth and regular, such as is obtained by machine gas cutting, full bends can be attained at higher hardnesses than where the surfaces are irregular in contour. The anvil-bend test is particularly valuable in evaluating the utility of various grades of cutting workmanship.

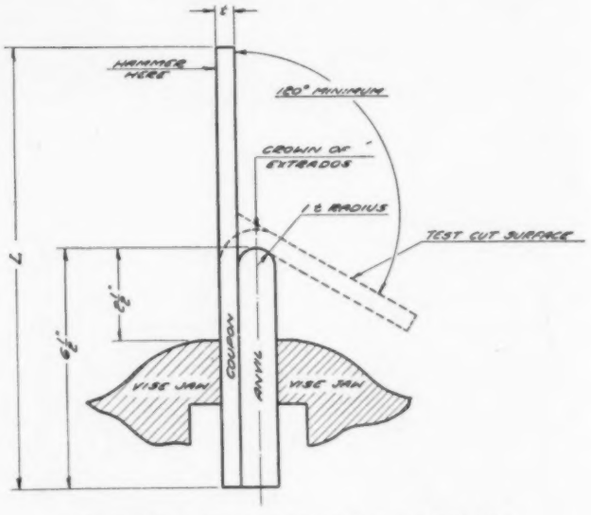


Fig. 13—Diagram Showing the Set-Up for the Anvil-Bend Test

The point of workmanship of cutting is important and observations point to smooth cutting for most economical and reliable results.

Macroscopic and microscopic tests of the heat-affected zones of plain and flame-softened cuts, the latter using post heat, were made concurrently by Union Carbide and Carbon Research Laboratories, Inc., in nickel, silicon and manganese structural steels to ascertain the depth of these zones below the surface of the cut and the character of their structural constituents. The chemical composition of the steels investigated, as determined by the laboratory, was as follows:

	Nickel Struc. Steel	Silicon Struc. Steel	Manganese Struc. Steel
Carbon	0.25	0.36	0.27
Manganese	0.64	0.94	1.40
Silicon	..	0.31	0.19
Nickel	3.32	..	..

The depth of the zones heated to temperatures which were high enough to alter the internal structures of the

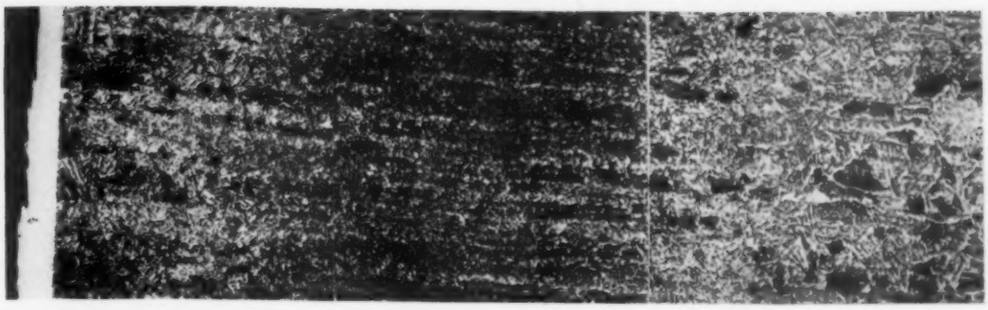


Fig. 14a—(100 X). The Structure at the Cut Edge of an Unsoftened Nickel Steel Specimen. The Narrow White Band Along the Cut Edge at the Left-Hand Side of the Print May Be an Oxide Although Appearing as Austenite at This Magnification. Its Thickness Is of the Order of a Few Thousandths of an Inch and It Is Relatively Soft. The Dark Material at the Interior Edge of This Band Is Martensite That Has Begun to Separate from the White Constituent While the Dark Material Immediately to the Right of the White Band is Martensite Which in the Print Extends for a Depth of 6 inches; Therefore, the Actual Depth of This Material Is 0.06 In. Then Comes a Transition Zone Which Includes More and More of the White Ferrite, and Finally at the Extreme Right of the Print Is Shown the Unaffected Steel Whose Structure Consists of Ferrite and the Dark Pearlite. (Photo Reduced to 1/2 Size in Printing)

steel and thus change their physical properties were found to approximate 0.04 to 0.08 inch in 1 inch thick steel, the narrow depth applying to structural silicon steel, the intermediate depth to structural manganese steel and the maximum depth to structural nickel steel. These depths are not materially altered in the heavier gages.

The hardness in these affected zones graduates to the normal hardness of the unaffected parent metal and therefore the depth of injurious hardening was somewhat less than that reported above. If there are irregularities in the cut surface due to improper operation of the cutting apparatus, the depth of injury must be measured from the roots of such irregularities. Plain flame cutting in these grades causes carburization of the surface of the cut to a depth of 0.002 inch to 0.003 inch and the cooling that follows cutting is rapid enough to produce hardening to a depth of approximately 0.03 to 0.07 inch and to affect the structure in a transition zone approximately 0.015 inch wide in which the hardness and the structure gradually vary from the very hard conditions wherein the structural constituent is martensite, to the original structure consisting of pearlite and ferrite produced in the normal cooling from rolling temperatures.

The size of the structural constituents in the hardened zones was seen to be much smaller than in the parent metal. In other words, flame cutting operated to refine the grain.

With each steel, the flame-softening operation tempers the martensite and eliminates the structure representing the brittle condition. As the flame-softening treatment is carried on below the critical point of the steel, neither the microstructure or the physical properties of the underlying steel having normal ferrite and pearlite structure, are changed, but the reheating does change the martensite structure to leave a tough and ductile, fine grain steel along the cut edge.

It was, therefore, the laboratory's conclusion that the steel in the heat-affected zone which was flame softened by postheating, is given a desirable combination of hardness and ductility, and the martensitic structure produced by the usual flame cutting procedures is tempered to a practically ideal condition.

Photomicrographs of the three grades under discussion, nickel, silicon and manganese structural steels, which bear out the foregoing representations, are reproduced in Figs. 14, 15 and 16. The magnification of 100 diameters was used for these three figures. Further examinations of the affected zones of the manganese and nickel grades were made at higher magnifications, which are reproduced in part and explained in Figs. 17, 18, 19 and 20.

Figures 21*a*, *b* and *c* illustrate the significance of postheat treatments as compared with preheat treatment in flame softening a grade of steel critically responsive to air hardening, emphasizing the need for proper application of the supplementary heat treating operations. The material in this case is a structural nickel steel of 0.33% carbon, 3.21% nickel and 0.26% copper.

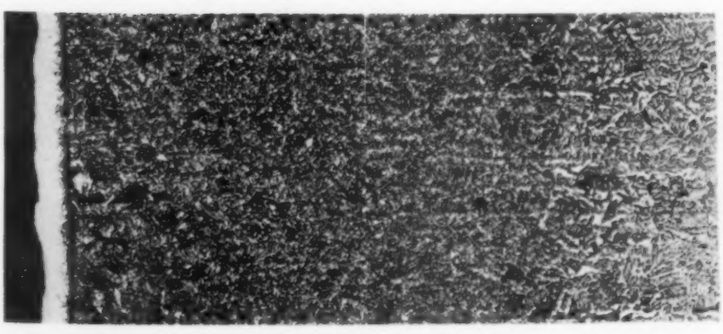


Fig. 14b—(100 X). The Structure of a Specimen from the Same Nickel Steel Shown in Fig. 14a, but in This Case the Postheating Treatment Was Applied. The Material in the Narrow White Band Proved to Be Quite Stable and Was Not Appreciably Altered by the Postheating. However, the Martensite Has Been Tempered to a Considerable Degree. The Acicular Constituent and Clear-Cut Widmanstatten-Like Arrangement Shown in Fig. 14a Have Been Practically Eliminated. The Transition Zone Between the Tempered Martensite and the Original Structure Is Wider in the Postheated Specimen Than in the One Shown in Fig. 14a, Cut Without This Treatment. (Photo Reduced to 1/2 Size in Printing)

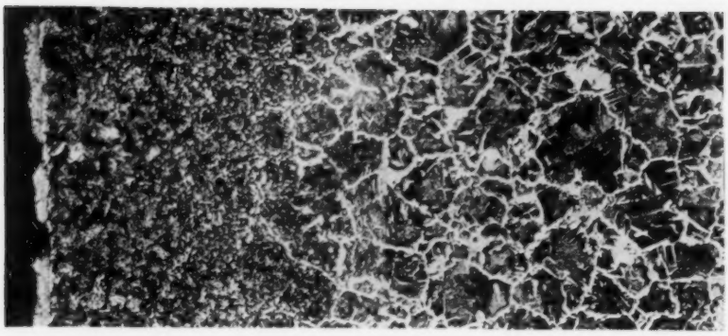


Fig. 15a—(100 X). A Silicon Steel Specimen, Cut Without the Postheating Treatment. The Irregular Light Colored Area at the Left Appears as Cementite. It Is Surrounded by the Dark Constituent Called Troostite. Below This Irregular Surface Layer the Structure Consists Mostly of Martensite, but Some Troostite Is Present. In the Transition Zone the White Ferrite Gradually Becomes More Sharply Defined Until the Unaffected Grains of the Original Structure Are Reached. The Dark Material in the Transition Zone Is Fine Grained Pearlite That Was Not Heated to a High Enough Temperature to Enable Transition Into a Harder Constituent. (Photo Reduced to 1/2 Size in Printing)

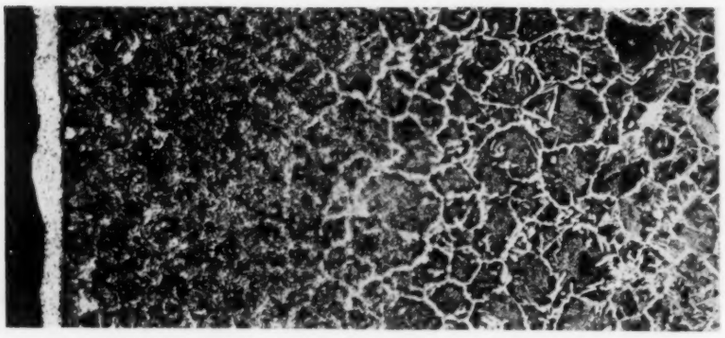


Fig. 15b—(100 X). The Same Silicon Steel Shown in Fig. 15a Except Here the Postheating Treatment Was Used. The Light Colored Zone at the Treated Surface Remains but the Surrounding Metal Has Been Tempered by the Treatment. The Dark Zone Adjoining the Light Colored Surface Layer Consists of Tempered Martensite and Some Troostite. The Next Is the Very Fine Grained Sorbitic-Ferritic Structure in Which Gradually Increasing Amounts of Ferrite May Be Observed as the Unaffected Metal Is Approached. (Photo Reduced to 1/2 Size in Printing)

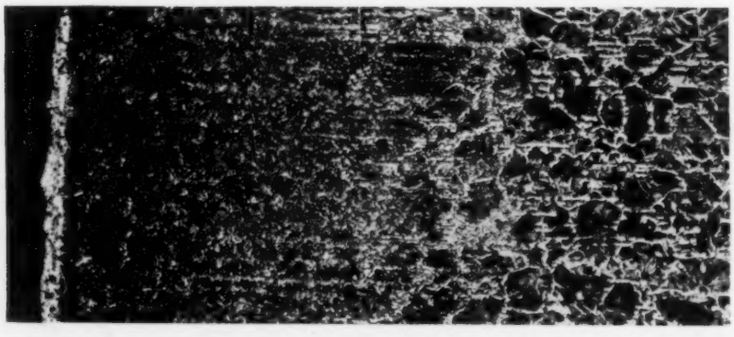


Fig. 16a—(100 X). The Structure of Manganese Structural Steel Specimen Taken from an Edge That Was Cut Without the Postheating Treatment. The Characteristic Outer Zone of Light Colored Metal Has a Matrix of Dark Troostite. Then the Underlying Dark Material Is Martensite with Some Troostite and a Small Amount of Free White Ferrite. The Transition Zone Is Fairly Narrow, and as in Other Specimens, the Free Ferrite Increases in Amount as the Unaffected Structure Is Neared. (Photo Reduced to 1/2 Size in Printing)

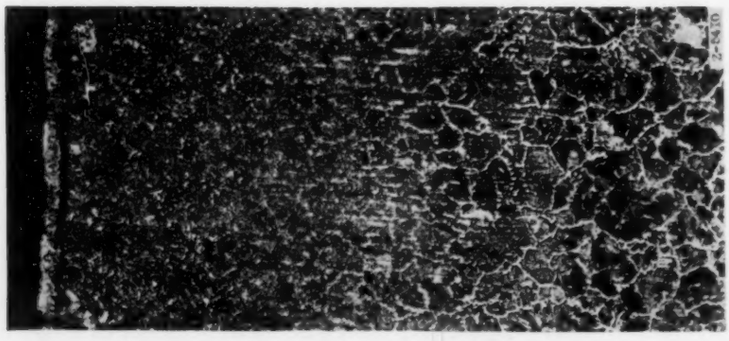


Fig. 16b—(100 X). The Structure of a Postheated Manganese Steel Specimen. The Surface Zone Contains Much Less of the White Constituent and the Underlying Dark Material Has Lost the Acicular Appearance That Is Representative of Martensite. It Has Been Tempered by the Postheating Treatment. The Transition Zone in the Treated Specimen Is Wider, and Changes Occur More Gradually Than in the Specimen That Was Cut Without Treatment. (Photo Reduced to 1/2 Size in Printing)

DRIFT TESTS

It was the recommendation of Mr. C. F. Goodrich, Chief Engineer of American Bridge Co. during the course of shop demonstrations at Ambridge Plant, that flame-softened cut edges in a representative group of high-tensile structural steels be subjected to drift testing inasmuch as certain specifications for these grades of steel require this test. In substance, the test requires that punched or drilled holes spaced approximately two diameters from a planed edge shall stand drifting until the diameter is enlarged 5% without cracking metal.

Fig. 17—(500 X). This Photomicrograph Shows, at Five Times Higher Magnification, the Structure at the Cut Edge of the Manganese Steel Specimen Which Is Illustrated at 100 Diameters in Fig. 16a. This Edge Has Been Carburized by the Cutting. The Massive Rather Indistinct White Constituent Near the Edge Is Surrounded by the Black Material Called Troostite. The Smooth White Material About an Inch from the Edge in the Photomicrograph Is Austenite, and from This the Gray Acicular Martensite Has Been Precipitated. Below This Is Light and Dark Gray Acicular Martensite Arranged In a Fairly Coarse General Pattern That Is Called Widmanstatten Structure. Steel with Martensitic Structure Is Hard and Brittle, and These Properties Are Given to a Moderately Less Degree by Troostite. The Large Proportion of the Massive Carbides at the Edge Also Contributes to the Hardness and Low Ductility

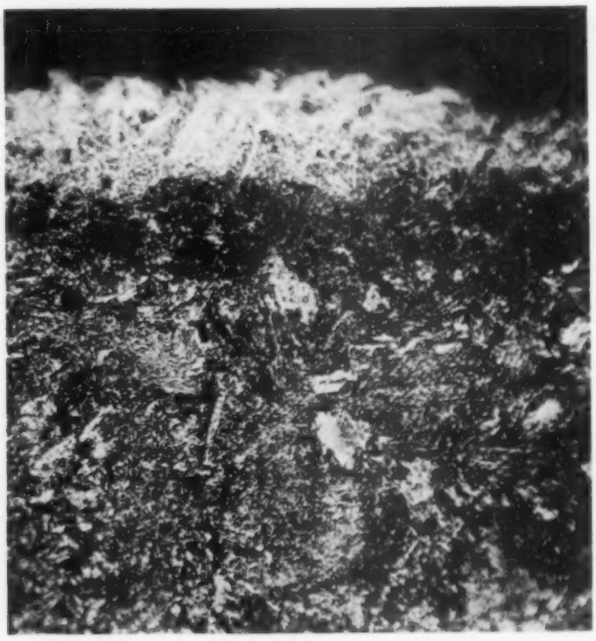


Fig. 18—(500 X). The Structure Illustrated Is the Same as Is Shown at the Lower Magnification in Fig. 16b. This Is the Flame-Cut Edge of Manganese Steel Specimen. The Postheating Treatment Was Used with the Cutting, and the High Magnification Makes Much More Evident the Great Difference Between This Structure and That Illustrated in Fig. 17 Produced by Cutting Without the Heat Treatment. Some of the Massive Carbides Are Retained at the Edge but the Austenite, Troostite and Martensite Have Been Tempered and Changed to Extremely Fine Carbides in a Ferrite Matrix. The Matrix Containing the Carbides at the Cut Edge Has Also Been Changed to a Condition Similar to That of the Structure Away from the Edge. Steels Having This Tempered Structure Have Favorable Combination of Strength and Ductility

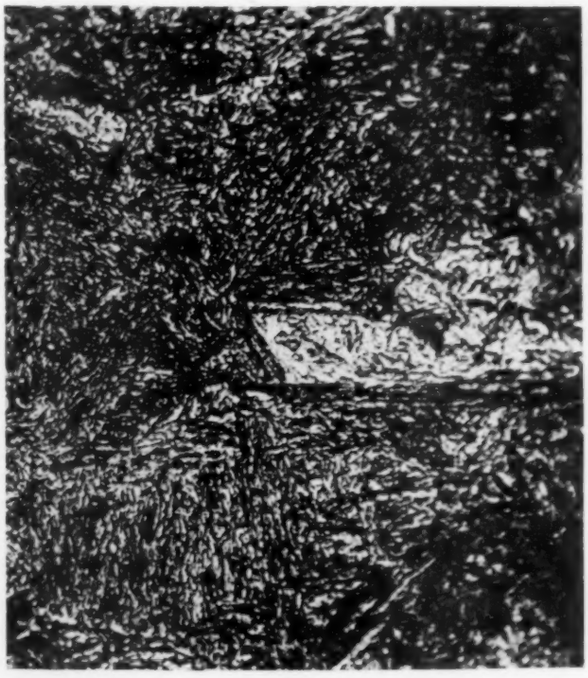


Fig. 19—(1500 X). The Photomicrographs in Figs. 19 and 20 Were Taken at Magnification of 1500. This Very High Magnification Was Used to Illustrate More Clearly Than Was Possible in the Earlier Illustrations, the Difference in Appearance Between the Martensite Produced in Cutting Low-Alloy Steels and the Tempered Martensite That Results from the Postheating Treatment. The Areas Photographed Were Located About 0.01 Inch to 0.02 Inch from the Cut Edge. In the 100 Diameter Photographs This Would Be 1 to 2 In. from the Edge. The Material Is $3^1/_2$ Per Cent Nickel Steel Containing 0.33 Per Cent Carbon. The Needle-Like Parts That Made Up the Structure Are Arranged in a Rather Coarse Angular Pattern. This Martensite Structure Is Produced by Rapid Cooling of the Steel from a Red Temperature

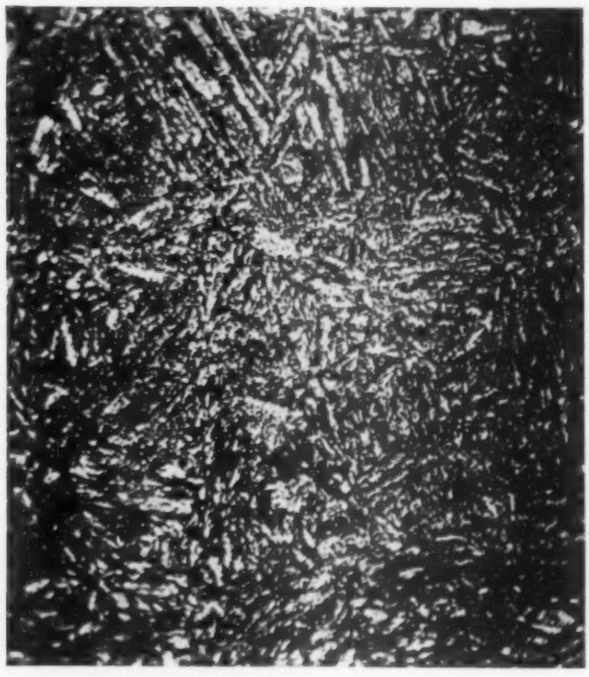


Fig. 20—(1500 X). This Is the Tempered Martensite Produced by the Combination of Cutting and Postheating. The Reheating of the Steel Has Changed the Microstructure and the Needle-Like Constituent Has Been Changed to a Matrix of Ferrite Containing Completely spheroidized Carbides That Are Finely and Uniformly Dispersed. Traces of the Former Coarse Angular Arrangement of the Structure Are Still in Evidence. The Ferrite Matrix Accounts for Ductility, and Strength and Moderated Hardness Are Given by the Fine Distribution of the Carbides. If the Structures of the Manganese Steel Shown at 500 Diameters in Figs. 17 and 18 Were Still Further Magnified to 1500 Diameters It Would Be Similar in Appearance to the Structures in Figs. 19 and 20. This Refers to the Structures About 2 Inches from the Edge in Figs. 17 and 18

Fig. 21a—(1500X). The Structure at the Edge of a Specimen of Structural Nickel Steel Prepared by Plain Flame Cutting. The Light-Colored Edge Zone Which Appeared as Austenite at 100 Diameters (Fig. 14a) Is Found at This Magnification to Consist of Two Layers; the Inside, Slightly Darker Portion, Probably Represents the First Stages in the Decomposition of the Austenite. This Slightly Darker Zone Contains Needles of Martensite Extending Throughout Its Limits. The Next Zone of Dark Constituents, as Shown in the Photomicrograph, Is Uniformly Martensitic Having a Decided acicular Structure. This Structure Is Representative of Steel That Is Hard and Brittle

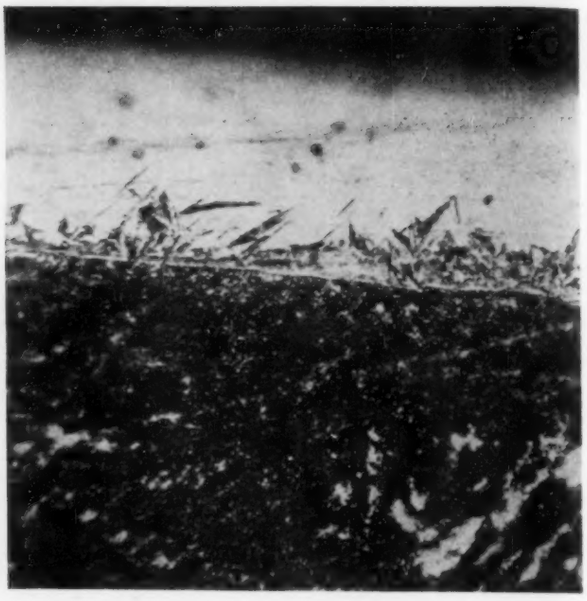


Fig. 21c—(1500X). The Structure of a Nickel Steel Specimen That Was Simultaneously Cut and Postheated. The Outer White Layer Appears to Be Austenite and at the Lower Edge of This White Material a Few Tempered Martensite Needles May Be Seen. The White Layer Did Not Extend Throughout the Specimen That Was Examined. Near the Top of the Plate Where the Postheating Temperature Was Highest, the Structure Up to the Cut Edge Consisted of Minute Spheroidized Particles of Cementite in a Ferrite Matrix. The Main Dark Area of the Photomicrograph Consists of Structure in Which the Acicular Martensite Originally Present Has Been Completely Spheroidized. This Structure Is Representative of Steel That Is Good in Respect to Both Toughness and Ductility

Fig. 21b—(1500X). An Area at the Borderline Between an Austenite-Martensite Structure of a Specimen of Nickel Steel Which Has Been Simultaneously Preheated and Cut. The Upper Half of the Photograph Shows Dark Martensitic Needles Geometrically Spaced in a Background of Light-Colored Austenite. There Are Indications That the Austenite Has Probably Broken Down Into What Is Known as White Martensite, Which Could Be Developed by Deeper Etching. The Very Dark Areas in the Lower Half of the Figure Are Troostite Patches and the Lighter Areas Are Sorbite; The White Constituent Is Ferrite. This Structure Is Also Representative of Steel That Is Hard and Brittle

This test was carried out in three grades of $^{7}/_{8}$ inch thick high-tensile structural steel having the following average composition:

	C	Mn	Si	P	S	Ni
O. H. Structural Mn Steel	0.35	1.43	0.196	0.028	0.027	
O. H. Structural Silicon Steel	0.38	0.86	0.312	0.021	0.034	
O. H. Structural Nickel Steel	0.39	0.66	0.124	0.037	0.020	3.32

Each plate was finished 16 x 16 inches having the following edge preparations:

Edge No. 1: Sheared
" No. 2: Sheared to $^{1}/_{4}$ inch full size and planed to size
" No. 3: Plain flame cut
" No. 4: Cut and flame softened simultaneously by Type I treatment

Three $^{13}/_{16}$ inch diameter holes were drilled at the quarter points along each side and 2 inches back from the edge. These holes were then drifted by means of drift pins having diameters progressively increasing by $^{1}/_{8}$ inch which were forced through the drilled holes with a steam hammer. The center hole and quarter point hole in each type of edge preparation received this test.

The amount of enlargement of the drifted holes and the edge deformation are shown and indicated in Fig. 22. The planed edges marked No. 2 and the flame-softened edges marked No. 4 withstood drifting to $1^{9}/_{16}$ inch, or approximately 100% enlargement without cracking, at which point the test was stopped.

The sheared edges, marked No. 1, cracked visibly during the $1^{5}/_{16}$ inch drift, or at an enlargement of approximately 60%, while the plain gas cut edges, marked No. 3, cracked during the $1^{1}/_{16}$ inch and $1^{3}/_{16}$ inch drifts, representing enlargements averaging approximately 40%.

The test demonstrated beyond question the ability of the flame-softened edges to withstand tests of this character.

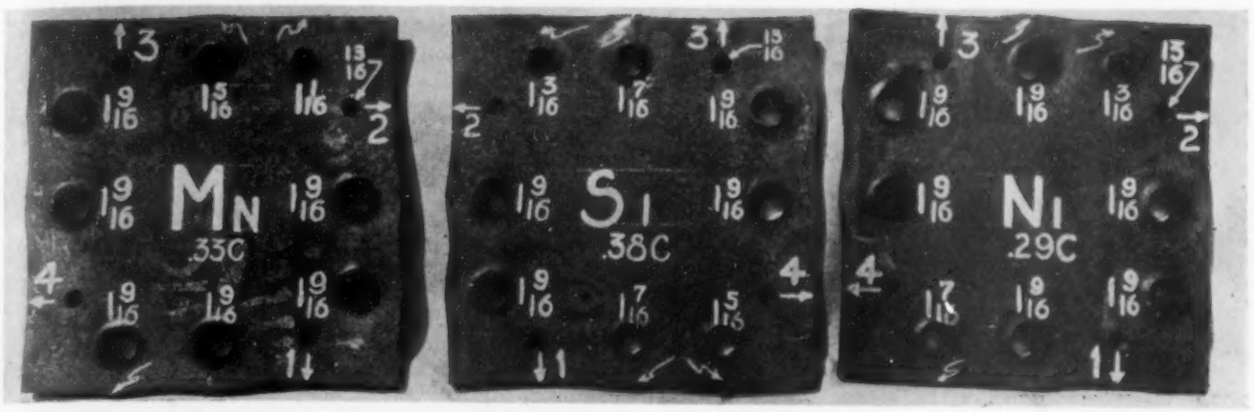
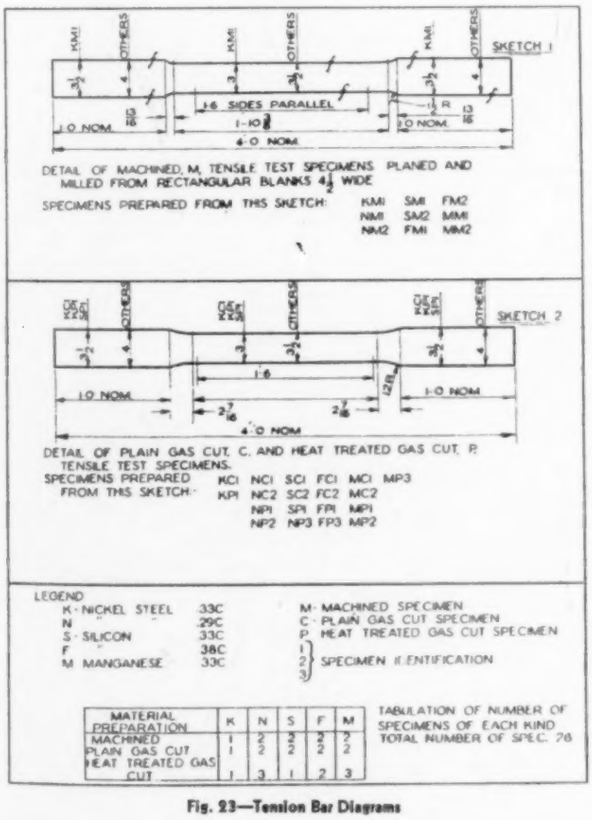


Fig. 22—Drift Tests in Manganese, Silicon and Nickel Steels

TENSION TESTS

It was Mr. Goodrich's further suggestion that large size tension bar tests be made of the several edge preparations to provide a more practical example for comparative study of their effect upon the overall physical properties of the steel, and accordingly a series of bars ranging in width from 3 inches to $3\frac{1}{2}$ inches at their reduced section by 48 inches long were prepared in three grades of high-tensile structural steel. Each series embraced machined, plain flame-cut and flame-softened flame-cut edges.

The diagrams and detailed information of the bars is reproduced in Fig. 23, and the mill test report of the physical properties submitted by the Homestead Plant of Carnegie-Illinois Steel Co. where these tests were made is reproduced in Table No. 2.


SKETCH 1
KMI
OTHERS
1-6 SIDES PARALLEL
1-0 NOM.
4-0 NOM
DETAIL OF MACHINED, M, TENSILE TEST SPECIMENS PLANED AND MILLED FROM RECTANGULAR BLANKS 4½ WIDE
SPECIMENS PREPARED FROM THIS SKETCH: KMI SMI FM2 NMI SM2 MMI NM2 FMI MM2
SKETCH 2
DETAIL OF PLAIN GAS CUT, C, AND HEAT TREATED GAS CUT, P, TENSILE TEST SPECIMENS.
SPECIMENS PREPARED FROM THIS SKETCH: KCI NCI SCI FCI MCI MP3 KPI NC2 SC2 FC2 MC2 NPI SPI FPI MPI NP2 NP3 FP3 MP2
LEGEND
K - NICKEL STEEL .33C
N .29C
S - SILICON .33C
F .38C
M MANGANESE .33C
M - MACHINED SPECIMEN
C - PLAIN GAS CUT SPECIMEN
P - HEAT TREATED GAS CUT SPECIMEN
SPECIMEN IDENTIFICATION
TABULATION OF NUMBER OF SPECIMENS OF EACH KIND TOTAL NUMBER OF SPEC. 78

MATERIAL PREPARATION	K	N	S	F	M
MACHINED	1	2	2	2	2
PLAIN GAS CUT	1	2	2	2	2
HEAT TREATED GAS CUT	1	3	1	2	3

Fig. 23—Tension Bar Diagrams

The physical properties of the bars having flame-softened edges are seen to be in good agreement with those having planed edges, in contrast to the flame-cut bars which failed at reduced loads. The ductility of the flame-softened edges in comparison with machined and plain flame-cut edges is illustrated in Fig. 24 for a 0.29% carbon-nickel steel.

The reduction of area of the flame-softened bar at the right is of the same order as that of the planed bar on the left, while the plain flame-cut bar is seen to have an abrupt fracture with negligible reduction of area.

FLAME-SOFTENING COSTS

The cost of flame softening for Types I and II treatments is mainly a matter of increased gas consumption

SPECIMEN NUMBER	WIDTH	THICKNESS	NOMINAL AREA	LOAD AT YIELD POINT	LOAD AT ULTIMATE STRENGTH	YIELD POINT	ULTIMATE STRENGTH	ELONGATION		
								LENGTH	INCREASE	%
KM-1	3.000	0.785	2.355	163,880	243,000	69,580	103,000	18	2.70	15.00
KC-1	2.925	0.785	2.296	155,600	202,800	67,770	88,330	18	0.30	1.67
KP-1	2.915	0.783	2.282	164,600	233,600	72,140	102,400	18	2.20	12.20
Mill Test						64,370	104,150	8		17.6
NM-1	3.498	0.880	3.078	209,100	305,900	67,940	99,360	18	2.75	15.28
NM-2	3.495	0.880	3.075	206,000	306,620	67,000	99,710	18	2.50	13.89
NC-1	3.490	0.865	3.088	226,300	275,300	73,280	89,150	18	0.32	1.77
NC-2	3.420	0.850	3.043	208,600	267,700	68,560	87,980	18	0.30	1.66
NP-1	3.450	0.890	3.070	199,300	296,600	64,940	96,620	18	2.46	13.67
NP-2	3.420	0.890	3.044	197,200	295,900	64,780	97,200	18	2.10	11.67
NP-3	3.400	0.890	3.026	200,300	293,000	68,100	99,600	18	2.64	14.67
Mill Test						64,150	99,420	8		16.7
SM-1	3.500	0.875	3.062	134,800	250,300	44,020	81,750	18	2.76	15.33
SM-2	3.500	0.880	3.080	133,100	245,700	43,220	79,780	18	2.32	12.89
SC-1	3.510	0.875	3.071	127,800	208,700	41,620	67,960	18	0.56	3.11
SC-2	3.480	0.875	3.045	128,300	226,000	42,130	74,220	18	1.12	6.22
SP-1	2.930	0.880	2.578	121,400	206,800	47,140	80,300	18	3.40	18.89
Mill Test						49,800	85,525	8		23.5
FM-1	3.495	0.890	3.110	148,600	281,900	47,790	90,650	18	3.50	19.44
FM-2	3.490	0.890	3.106	143,900	281,100	46,380	90,600	18	3.76	20.89
FC-1	3.480	0.890	3.097	149,300	238,300	48,210	73,800	18	0.60	3.33
FC-2	3.400	0.890	3.026	145,300	217,400	48,040	71,850	18	0.44	2.44
FP-1	3.480	0.890	3.097	163,300	282,400	52,720	91,180	18	2.80	15.56
FP-3	3.510	0.895	3.126	178,800	290,300	57,200	92,830	18	2.20	12.22
Mill Test						50,340	92,990	8		21.0
MM-1	3.500	0.875	3.064	161,300	283,200	52,640	92,430	18	3.38	18.78
MM-2	3.500	0.875	3.064	160,200	285,200	52,280	93,080	18	3.10	17.22
MC-1	3.540	0.870	3.079	162,300	208,600	52,710	67,750	18	0.25	1.39
MC-2	3.460	0.875	3.054	160,600	217,100	52,580	71,090	18	0.30	1.67
MP-1	3.400	0.880	2.993	172,400	278,140	57,600	92,940	18	2.80	15.56
MP-2	3.400	0.885	3.009	171,900	278,200	57,130	92,460	18	2.70	15.00
MP-3	3.460	0.885	3.062	186,100	282,900	60,090	91,350	18	3.25	18.06
Mill Test						68,040	97,700	8		18.25

Table 2—Tensile Test Results (The Legend for the Type of Steel and Treatment Is Shown at the Bottom of Fig. 23)

Fig. 24—Tensile Test Bars. Note the Ductility of the Flame-Softened Bars (Outer) Compared with the Plain Gas-Cut Edge (Center)

inasmuch as the operation is carried out simultaneously with cutting and at the usual cutting speeds, and therefore, no appreciable amount of extra labor is involved.

For the Type III treatment, which is non-simultaneous with cutting, the costs involve both gas and labor. However, with this type of treatment the operation is usually conducted at a faster rate of speed and therefore the cost by this method may be only slightly greater than that softened by the Types I or II treatments for the same unit of surface area softened. As the neutral flame is employed in flame-softening operations, the multi-flame heads consume equal quantities of oxygen and acetylene for the burning ratio for the neutral flame in atmospheric air for the two gases is of the order of 1:1.

For estimating purposes the volume of oxygen and acetylene for softening $^{3}/_{4}$ inch to $1^{1}/_{4}$ inch thick steel by the simultaneous Type I treatment may be figures at approximately 2 cubic feet of each gas per linear foot of cut for each side of the kerf softened.

For Type II treatment the consumption is somewhat lower.

For Type III treatment, equivalent surface areas can be softened with approximately one-third to one-half less gas.

The gas consumption per unit of time is dependent upon the size of the tips in the multi-flame heads and the specific flame characteristics, a function of gas pressure. The length of the inner cone of the neutral flame serves as a yardstick for predetermining heat quantity necessary for any particular operation, and may be readily measured by a suitable metal scale. An inner cone length of approximately $^{5}/_{16}$ has been found to give good results for most applications.

RANGE OF FLAME-SOFTENING APPLICATIONS

Some of the obvious applications for flame softening are here listed, referring to quench and air-hardening steels:

1. Suspension bridge towers: Shaping of gusset plates, web plates including manholes, hand holes and lightening holes in web plates.
2. Bridges: Shaping of web plates for arch bridges, gusset plates, some cover plates and end cuts for Universal mill plates, manhole cutting in truss bridges and web shaping, and miscellaneous plates for cambered girder bridges.
3. Buildings: High-tensile gusset plates for new and alteration work, narrow high-tensile girders.
4. Railroad Vehicles: Low-alloy high-strength steel, plates for sides and bottoms, center sills and built-up and pressed bolsters and side frames, hand and service holes in center sills and bolsters, correction cuts.
5. Industrial Equipment: Straight-line and shape cutting in all grades of high-strength structural steel, including architectural openings and hand and service holes for finish cutting or to allow free machining.
6. Steel Warehouses: Finish cutting, straight and shape, all hard or high-strength steels, and for annealing surfaces hardened by friction saws so they can be readily machined, for cut edges of high-carbon pipe so they can be machined or threaded.
7. Foundries: Softening gas-cut surfaces for all clean-up cuts in casting of alloy steels that respond to short time heat treatment.
8. Steel Mills: Cut surfaces in carbon steels of 0.40% carbon and higher, and all alloy grades, to prevent cracking upon cooling, or to permit machining or for finish cutting to customer's specifications.

Grateful acknowledgment is made to the American Bridge Company for furnishing the greater part of the high-tensile structural steels used during the laboratory and field experimental work, and particularly to the latter company for furnishing facilities and assistance and counsel for shop tests at Ambridge and Gary Plants, and for arranging for the tension bar tests at the Homestead Plant of Carnegie-Illinois Steel Company; and to Union Carbide and Carbon Research Laboratories, Inc. for concurrent assistance throughout the period of experimentation and testing.

Assembly Plant for the Welding of Barges*

Discussion by E. C. RECHTIN†

THERE are two questions, which I would like to raise in connection with Mr. Wolfe's very interesting description of the Dravo assembly plant, principally because I know from preliminary discussion with Mr. Wolfe, that he has very definite answers to the points in question, and because I believe that the members of the Society would be, as I was, greatly interested by his answers.

Some years ago the original proponents of the idea of welded barges used to preach that the ideal way of building them was to lay some timbers on a mudflat, hire a locomotive crane or a gin pole and a welding outfit, and start in to produce welded barges. Undoubtedly there were a number of barges built under these conditions, and in fact there are still some localities where this method is being practiced.

It is interesting to note, however, from Mr. Wolfe's description that this fashion has changed radically. To refer for the moment back to Mr. Jackson's paper "Welding in Tanker Construction," I believe you will all agree that the impression obtained is one of a very considerable amount of equipment involved. I was fortunate to be able to attend the meeting of the Naval Architects last summer, at which time we were all the guests of the Sun Shipbuilding and Drydock Co. on a most interesting inspection trip of the equipment described in Mr. Jackson's paper. I wish to take this oppor-

* Paper by Mr. George F. Wolfe published in Oct. 1937 issue, THE WELDING JOURNAL.

† United Shipyards Inc.

tunity to express my personal thanks for this opportunity.

We have then today been presented with two different new developments in welding technique, both of which, however, contain the common ingredient of heavy investment.

Investment, of course, carries with it increased fixed charges, and we quickly meet with the accountant, who recalculates our overhead with somewhat surprising and unpleasant results. The point that I wish to make is that such an investment must carry with it possibility of repetition of the work in question. In the case of the Sun Shipyard they are fortunate that they have been able to confine their output principally to tankers, on which their automatic process can be continuously used.

In Mr. Wolfe's description of the Dravo plant he astonished us by telling of a production speed, which has enabled them to launch a barge from this assembly line every other day. While we have found it difficult to appreciate what this means in terms of production, let us not overlook the fact that there must be a corresponding amount of activity and energy displayed in the sales department, to successfully and profitably dispose of such an output. Therefore, in the light of possibly slimmer markets I would like to have Mr. Wolfe present to this Society a description of one of the jobs, to which they have applied these assembly methods outside of the field of barges. Let me, therefore, frame a question:

Can you produce anything except barges with this assembly line?

The second question is raised by a comparison of Mr. Jackson's and Mr. Wolfe's papers. It will be noted that Mr. Jackson's paper particularly stresses the automatic welding feature, whereas this phase is in Mr. Wolfe's paper conspicuous by its absence.

I, therefore, believe the Society would be interested in having Mr. Wolfe tell us the status of automatic welding in the Dravo plant, and the question becomes:

How much automatic welding, if any, is done in connection with this assembly line?

Replies to Questions

By MR. GEORGE F. WOLFE††

IN answer to Mr. Rechtin's first question as to whether we can produce anything except barges with the assembly line method of production, we are pleased to state that although this assembly shop has been in operation only a few months we have already had occasion to adapt it to other usage in addition to the construction of barges.

Early in August we had an invitation to bid on Spillway Gates for the Pickwick and Guntersville Dams which are being constructed under the direction of the Tennessee Valley Authority. The Pickwick Dam requires twenty-three (23) gates and Guntersville Dam nineteen (19), making a total of forty-two (42) gates in all with each gate having an upper and lower leaf, the lower leaf weighing approximately 65 tons when fully assembled and the upper leaf approximately 40 tons. In bidding on this work, on which we were fortunate enough to secure the contract, we decided that the most practical method for the handling of these heavy pieces would be to utilize the straight line method of assembly in the barge assembly shop where the hydraulic transfer carriages would be available for the moving about of these heavy loads.

The gates are 20 feet in height and 41 feet in length with a flat skin plate carried on a system of horizontal supporting girders. The attachment of the skin plate to the girders is entirely by welding, there being no holes in the skin plate, while the balance of the construction, including the stiffening girders and various diaphragms, is entirely of riveted construction. The skin plate is in three strakes with the splicing of these strakes over the flanges of the girders. The splice is made by separating the plates 1 inch and running a $^1/_2$-inch continuous weld the full length of the gate on each side of the plate. Since this method of construction calls for a considerable amount of welding on both sides of the skin plate it is necessary to turn the fully assembled structural portion of the gate, weighing about 50 tons in the case of the lower leaf, completely over during fabrication in order to secure down welding. The straight line method of assembly fits in very nicely with this type of work and the barge shop equipment is quite sufficient for the handling of the loads involved.

The assembly of the various parts into complete units is started at the upper end of the shop and carried progressively forward until all riveting is completed as well as the welding on one side of the skin plate. The gates are then brought to a point where "A" frames are provided with temporary trunnions bolted to the ends of the gate and by means of this partial support the 50-ton units are readily turned over with the much lighter cranes overhead. The operation is continued into the next station where the completion of the gate is carried on which necessitates the boring of holes at each end for the axles and the installation of axles and rollers. The completed units, which weigh 65 tons in the case of the lower leaf and about 40 tons for the upper leaf, are then taken out on the transfer carriages similar to the movement of barges. The gate leaves are transferred to barges by means of a floating derrick for delivery to the respective dams.

With reference to Mr. Rechtin's second question regarding the use of automatic welding equipment in our operations we would state that so far none has been used. Over a period of several years we have sought suitable equipment from manufacturers of automatic welding equipment but in each instance the manufacturers' representatives, after looking over our operations have refused to recommend their equipment. The main reason for this inability to adapt automatic equipment to our operations is that we are using lap-welding on practically all of our work and our beads are seldom running over $^3/_8$ inch in size. We have recently made a careful investigation of the Union Melt Process as used at the Sun Shipbuilding Company and as described in Mr. Jackson's paper, and in spite of the manufacturers' lack of recommendation of this equipment for our operations, we have placed an order for one of these machines. We feel that certain research expenditures of this nature are essential to develop the adaptability of new welding methods.

†† Chief Estimator, Dravo Corp.

BOUND VOLUME JOURNAL

The AMERICAN WELDING SOCIETY has made arrangements for members who wish to have their Journals for 1937 bound in attractive, imitation black leather covers, to do so by sending copies of the twelve issues to Russell-Rutter Company, Thirty-Third Street and Eighth Avenue, New York, N. Y., Att. Mr. Russell Lauben, Jr. A special reduced rate has been arranged at $1.75 per volume providing the issues of the JOURNAL are sent to the binder on or before February 10th. The bill for the binding and return postage will be sent direct from the Society's office.

WELDING OF MECHANICAL AND STRUCTURAL PARTS in a General Equipment Shop*

By A. E. GIBSON†

FOR two days we have had papers presenting technical and research investigations. My contribution to this program is wholly practical. I have nothing new in the art to offer. My talk this morning, and the slides which will be shown, will, I hope, impress you with the trends of welding design and fabrication in the application of welding in the building of a wide variety of mechanical and structural parts in a general equipment plant.

We are conscious of the importance of design to the success of welded equipment. Prejudices of the past, the design of cast and riveted equipment, must be set aside and guided by a knowledge of the proper distribution of metal, we must design our weldments for maximum strength in tension, fatigue and impact, with minimum weight, if we are to obtain the potential advantages of the welding art.

The use of a plate brake and forming presses to shape metal is of importance not only for maximum strength, but to obtain low cost production. Included in the slides accompanying this talk is shown a brake forming a $^1/_2$-inch plate (Fig. 1) about twelve feet long being bent into a channel shape. The entire operation consumes but a few minutes including handling. Even under the most favorable method of automatic welding, the cost of producing the part with three pieces of steel welded together would be many times the cost of the part formed in the brake.

Another adjunct to welding, the positioning machine, is of great importance to low cost of welded equipment of considerable size and weight.

The possibility of obtaining low cost and at the same time increased strength, is shown in the picture of the corner bracket (Fig. 2). On the left is shown the cast design; on the right is the welded detail, and between the two are the pieces shaped preparatory to welding.

* Presented at Annual Meeting, AMERICAN WELDING SOCIETY, in Atlantic City, N. J., Oct. 1937.

† President, The Wellman Engineering Company.

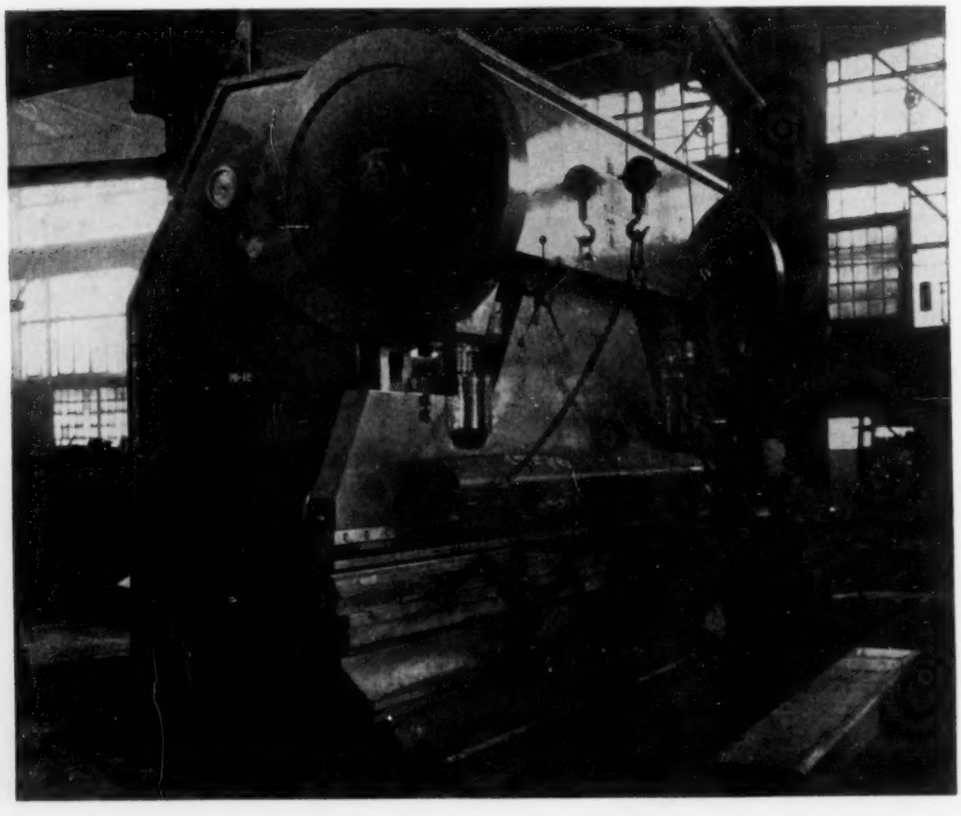


Fig. 1—The Use of a Plate Bending Brake, as Illustrated Here, Bending a ½-In. Plate 11 Ft. 2 In. Long, Makes Possible a Great Saving in Cost Over Welding Three Plates to Form the Shape. It Is Such Equipment as Plate Brakes That Is Playing an Important Rôle in Cost Reduction of Welded Equipment. Note That the Brake Is Itself 100 Per Cent Welded

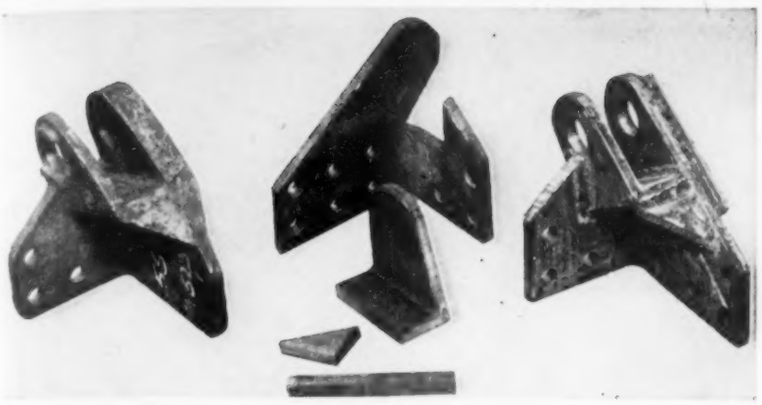


Fig. 2—The Corner Bracket at the Left Is an Original Design in Cast Steel. The One at the Right Is a Development in Welded Construction. No Failures of the Welded Design Have Ever Occurred, and Its Cost Is 40 Per Cent Under the Price of Castings

These brackets are produced 50 to 100 at a time, and the cost of the welded part is 40% under that of the cast piece. The replacement of castings which have failed in service is considerable. In two years use of the welded bracket, none have failed. There are literally thousands of instances where details now cast can be profitably welded, if sufficient study and thought is put into the redesign.

Standard rolled sections, angles, channels and beams play an important part in the modern design of mechanical equipment. The blast furnace skip hoist (Fig. 3) and the transfer car (Fig. 4) are good examples of the use of rolled sections. The base of the skip hoist (Fig. 3) is composed of 21½ inches, 142 lb. wide flange beams welded together to form a unit of great strength and rigidity. From a cost standpoint, the welded frame is below that of a casting without considering the pattern necessary to produce the casting. The only preparation of the material for welding consists of torch cutting or shearing the beams and plates. One would look far these days to find bed plates for electrical generating units not constructed of welded beams and plate, and their use has demonstrated their satisfactory performance from the standpoint of strength and rigidity.

In many instances the question of weight is of prime importance. Figure 5 is an example of weight reduction. This gear reduction base consists of beams, flame cut in the web with the flange bent and welded to the web and cast steel bearings welded to the upper flanges. The drums are also of welded design. In designs such as this the cross planing of the bearings for the caps can be done before welding the bases in place, thus eliminating the necessity of performing this operation on a large machine tool. Our experience is that the machine labor on welded equipment is materially less than that required for a similar casting, and the necessity for repairing defects, so often encountered in castings, is eliminated with rolled steel.

When considerable production is available, too much thought cannot be given to welding fixtures and jigs in order to eliminate labor. Figure 6 illustrates a fixture for welding two steel castings, machined before assembly, and forty lugs with finished tapered slots, welded to a U-shaped plate. While the initial investment in the fixture is considerable, it is quickly saved in the lowered man hours required and in the elimination of misalignment. Two sizes of frames were required and two welding fixtures provided. While the welding operator tack welds the parts in one fixture, the set-up man assembles the parts in the other, thus reducing to a minimum any loss of time of one operation holding up the other.

Within the last few years there has come onto the market a great variety of new steels generally known as low-alloy steels. These new materials have physical strengths far above low-carbon steels, and are playing an important part in designs where high strength, reduction of weight and resistance to corrosion and abrasion are desired. The use of these materials demands efficient design, the best of welding technique, and generally heat treatment after welding. Savings in weight of 30%, 40% and 50% are possible. Even with steels having yield strengths of 60,000 psi and ultimate strengths over

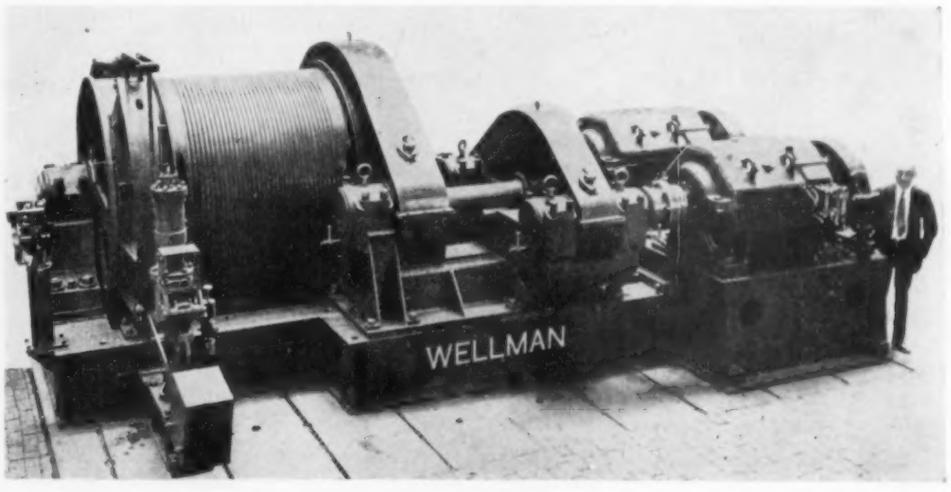


Fig. 3—A Welded Design Blast Furnace Skip Hoist Weighing Approximately 90,000 Lb. The Bed Plate Is of Heavy Wide-Flanged Beams, and the Gear Reduction Case Has Cast Steel Bearings Welded to the Plate

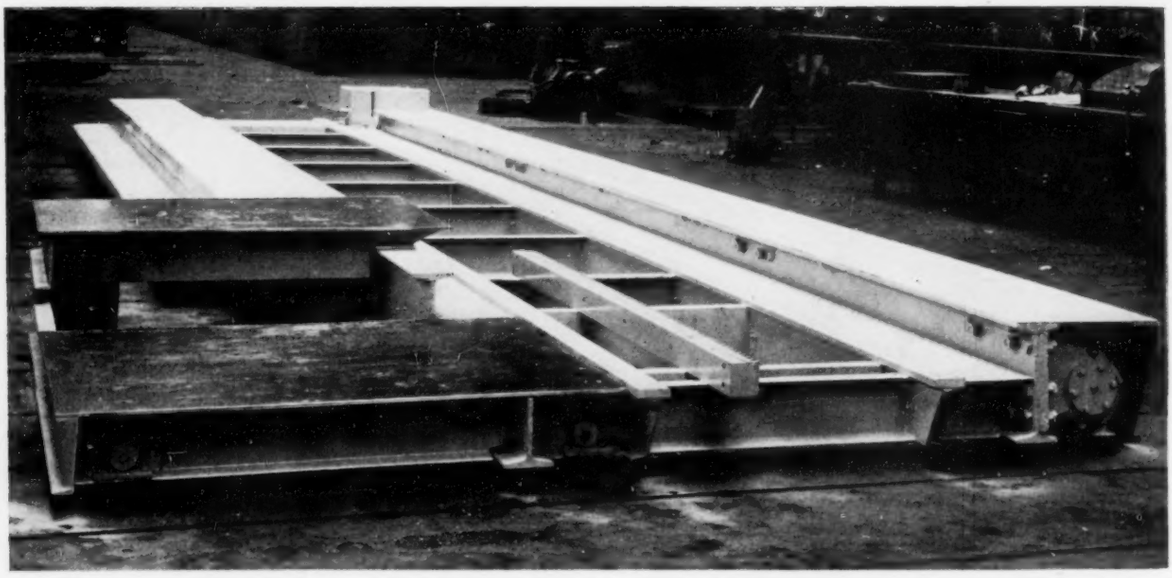


Fig. 4—Welded Transfer Car, Illustrating the Use of Rolled Angles, Channels and Beams in the Construction of Equipment of Light Weight

90,000 psi, it is possible to obtain equal filler metal values with plate up to $^1/_4$ inch in thickness by using alloyed electrodes. With heavier plate, weld sections as strong as the plate are possible with complete penetration reinforcing fillet welds.

We sell certain equipment of low-alloy steel, heat treated for strain relief, with a guarantee against breakage. This is impossible with castings or welded construction of low-carbon steel. Where resistance to corrosion or abrasion is desirable, certain low-alloy steels give excellent service and are finding an increasing demand in the trade. The nickel-copper steels and the copper-

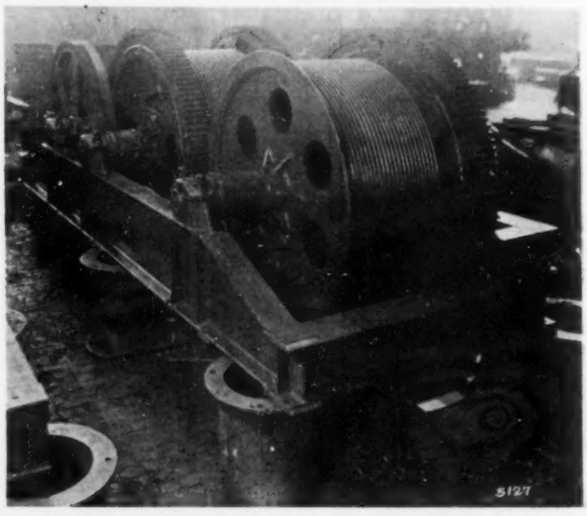


Fig. 5—One of Three Welded Bed Plates and Welded Drums Forming the Boom Hoist of Coal Loading Towers. Weight Reduction Was the Principal Reason for Welded Design. The Cost Proved to Be Substantially Under the Cast Design

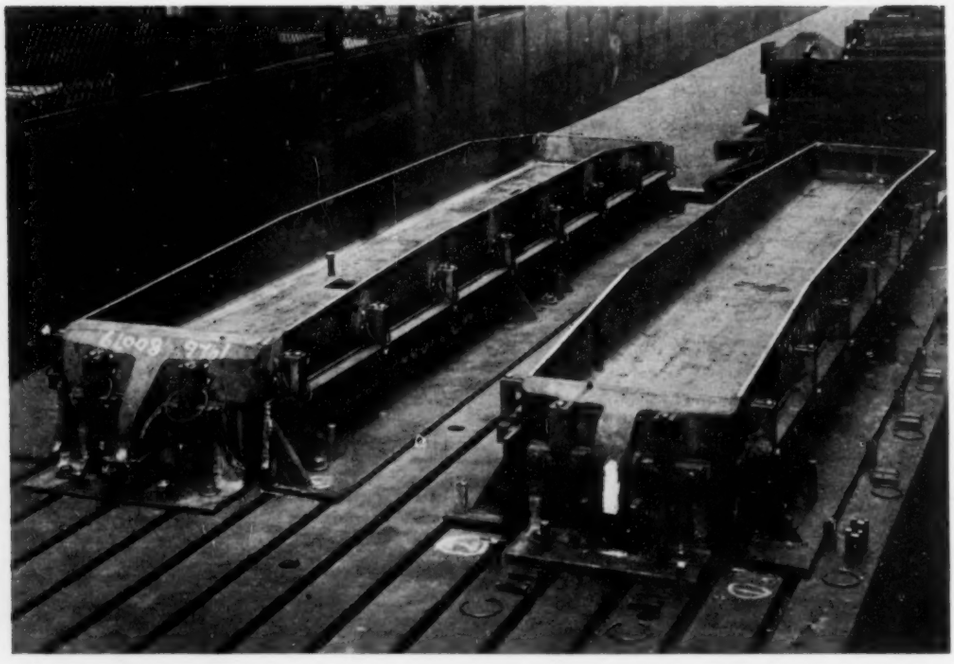


Fig. 6—Welding Fixtures Such as These Are Indispensable Aids in Low-Cost Welding and Interchangeability of Parts. While the Initial Investment Is Considerable, It Is Quickly Saved in Lowered Man-Hours and Eliminates the Possibility of Errors in Alignment

phosphorous steels are excellent for corrosion service. The carbon-manganese and the chromium-manganese steels give good results in abrasive service. Those steels which have a considerable air hardening property necessitate care in gas cutting and welding to prevent cracking or excessive brittleness. A first class operator can soon learn the proper technique, but it is advisable to consult the producer of the steel for the proper procedure, or to sufficiently test the material to eliminate the possibility of failure.

The ultimate scope of welding in the building of welded mechanical and structural equipment is largely a commercial consideration. The trade will always be willing to pay a higher price for a superior article. However, fabricators should be tireless in their efforts to reduce costs by efficient design and the use of efficient fabricating procedure and auxiliary equipment.

Welding is an exacting science, and the day when buying welding apparatus and the indiscriminate hiring of welding operators without qualification tests constituted a weldery, is past. Satisfactory results without competent supervision is as impossible in welding as in any other art. The sooner this is realized by industry, the sooner will we be free of costly failures which have in the past discredited welding. A failure in a casting is lightly passed over; a failure in a welded design condemns the art. I like the slogan of one of our welding equipment friends: "More and Better Welding."

MANAGEMENT OF—Machine Cutting Operations*

By R. F. HELMKAMP†

TO MANAGE any shop operation properly the executive must know something of the nature of the process involved, its range of usefulness, how, where and when to apply it to obtain economical and satisfactory results and know the present limitations as well. The more detailed information he acquires regarding the application of the process the better fitted he will be to regulate or direct by effort or skill and to make prudent or thrifty use of the means under consideration.

The application of machine gas cutting to general manufacturing problems has been relatively slow, since time was required to standardize cutting practice and cull out undesirable procedure. There has been a steady development by countless individuals and industries working with this process to increase its usefulness as applied to their particular problems. Such work has been going on for over a quarter of a century and when we consider that practically all investigations, whether fostered by individuals or industries, were carried on with serious intent to further their own interests, we can readily determine that the background of this process rests on sound engineering information. Other corollary developments in fusion welding, further developed the need for a quick, economical and dependable method of forming iron and steel to desired contour.

Problems arise daily in industry that are readily solved by the application of machine gas cutting. The oxyacetylene process literally presented itself to industry in general, through the back door, with the result that until recent years the shop men knew more of its value and application than the front office, or those in the executive capacity. Engineering organizations have been busy in the past few years analyzing the merits of the process, setting limitations based on investigations and writing codes for the guidance of the users of the process.

* Read at the 38th Annual Convention, International Acetylene Association, Birmingham, Alabama, November 10, 11 and 12, 1937.

† Engineer, Applied Engineering Department, Air Reduction Sales Co.

INVESTIGATE POSSIBILITIES OF APPLYING MACHINE GAS CUTTING

This all brings us to a point, where it is suggested that those in an executive capacity investigate the possibility of applying the process to any work under consideration whether redesign of present products or development of new. Should, for example, a plant executive provide each of his department heads with information available on machine cutting, with the request they study the process and think in terms of applying it to their problems, for a specified period of time, this executive could call a meeting at the expiration of the allotted time and develop many interesting applications of the process. Further study and cost analyses would indicate the course to follow.

The management of machine cutting operations means first an investigation of the practicability of applying the process to the work to be done. This brings up questions such as: What metals can be cut, what effect has gas cutting on the metal, what are the limitations as to thickness, what degree of accuracy can be obtained, are specially trained operators required, what are the cutting speeds, what machines are available and best suited, can production costs be predetermined, how do they compare with present practice and what will be the quality of the work?

The executive in direct charge of mechanical gas cutting operations should be familiar with the answers to these questions or know the proper representatives of the supply companies to contact for further information on specific problems. The services of such individuals are readily obtainable.

What Metals Can Be Machine Cut.—The knowledge that most ferrous metals, in general use, can be flame cut is generally understood. Steels under 0.30 per cent carbon can be cut cold, or without heat treatment before or after cutting. Machine gas cutting of these steels is just as well standardized and just as much a matter of

course as their shaping by any of the accepted machining methods.

Steels in the higher alloy group can also be cut without difficulty. These steels, however, should be preheated before cutting and annealed afterward. When this procedure is followed, there is no more of a problem than with the lower carbon steels.

Certain special alloy steels require a specific technique and procedure to produce satisfactory cut surfaces. Chromium alloys come under this general classification and good results with mechanical cutting may be had on this class of steel with a chromium content in the 4 to 6 per cent range.

Effect of Gas Cutting on Steel.—The management of machine cutting operations must consider the effect of flame cutting on the metals to be used. The facts are available to those interested in the metallurgy of it and have been published by various unbiased engineering organizations that have based their findings on numerous studies and analyses.

The results may be briefly summarized, though they have been verified over a long period of time by the experience of those employing the process in accordance with clearly defined correct practice.

Flame cutting has no appreciable effect on the physical and chemical characteristics of the plain low-carbon steels which constitute the bulk of steels used in industry. That is why these steels are cut cold and need no heat treatment. Alloy steels and large forgings should be annealed and cut hot because of the strains inherent in them incident to the cut surface which results from the longitudinal shrink due to the heat of the cutting process. The correct information as to how to handle such materials should be in the hands of the foreman in charge. With such information and procedure properly understood and applied, results will be consistent and satisfactory.

Annealing Steels with Higher Carbon Contents.—Steels over 0.30 per cent carbon tend to have some migration of carbon to the flame-cut surface. When correct practice is followed and these steels are preheated before cutting and annealed afterward, they are just as easy to cut as the lower carbon steels, and can be machined afterward without difficulty. The annealing returns the steel practically to its original state. Extensive researches and tests, both in this country and abroad, have established this fact beyond a doubt.

All plate and forging thicknesses common to industry offer no difficulties to the machine gas cutting process. The oxyacetylene torch readily and smoothly severs sections far beyond the practical range of cutting by mechanical means.

Accuracy of Flame Cutting.—Flame cutting can be relied on for reasonable accuracy. The squareness and clean finish of such cuts, together with the sharp top and bottom edges, compares favorably with rough machining.

The degree of accuracy depends largely on the grade and thickness of the material, and the intricacy of the shape. Where no subsequent machine finish is required, ordinary steel plate or slabs up to about six inches in thickness may be generally cut right to the finish line. On the higher carbon steels and parts which are to be machine finished, only a sufficient tolerance need be left to allow for easy and economical machining. Such predetermined accuracy may be depended on for square edged and bevel cuts, including work of such a nature as double bevel cutting, swinging bevel cutting and the cutting of constant bevels on irregular contours. Considerable work is being done of the nature of cutting in two planes, to which such accuracy also applies.

Allowances for Kerf Width.—A simple rule-of-thumb, to apply for machining tolerance when required on thicknesses up to six inches, is to allow stock, the equivalent of the kerf of the cutting tip used, for the thickness of metal cut. For thicknesses greater than six inches a tolerance of $1^1/_3$ to 2 times the kerf width is suggested. As the operator acquires skill he can reduce such tolerances.

Since tolerance varies with the grade of work to be done, it may readily be compensated for by making due allowance on the drawing or templet used in cutting the shapes. The kerf or width of the metal dislodged by the cutting operation, is taken care of the same as tolerance. The allowance is normally no more than would be required with other methods.

Cutting Machine Operators.—Good machine cutting operators are readily developed from shop mechanics of average intelligence and ability previously trained in metal working. Men selected with the qualification of being conscientious workers with a pride in accomplishment and an interest in mechanical cutting will rapidly pick up the details of flame cutting. The instructions furnished with machine installations and by service representatives are easy to follow and produce results quickly. Make the recommended adjustments to suit the thickness to be cut, as given in the set-up tables, and the rest is largely automatic. With proper procedure you get good results at once, and get them most economically.

Best practice is to train more than one operator so as to avoid temporary stoppage of operations due to illness, promotion or other reasons that would disturb the production schedule of the machine. Apprentices are usually employed as helpers, and thereby further increase the supply of skilled operators. Broadening operations that may require additional machines will then find you with the necessary operators.

Selection of Machines.—A study of the nature of the work to be done prompts the selection of the cutting machine or machines best suited. The manufacturers of gas cutting machines are broadening their scope and developing them more along regular machine tool lines so as to provide a selection of machines that are of the general purpose type, production type or highly specialized for specific work. These machines may be further classified as of the stationary, semiportable and portable type. There are machines of these types capable of extending the length of the cutting range indefinitely to that required for shop operations. Some machines are capable of special adaptations to specific operations not as yet common to industry in general. Some of this work is accomplished by special attachments to standard machines. In some cases special machines for special production operations are developed. From the foregoing it is quite evident to the manager of an industry that can and does use mechanical cutting that the field of application is constantly broadening.

There are various types of driving mechanisms employed on these machines. The selection offers a choice to suit the requirements of the user and the type of work under consideration.

Periodic discussions of machine cutting problems with the representatives of the various companies that distribute mechanical cutting machines will keep interested executives up to the minute on the latest developments of this important process. Considerable progress is being made in the line of additional and specialized machines and industry in general will profit most by keeping well informed on the latest developments.

Predetermining Production Costs.—Cutting speeds and gas consumption costs are items that vary, depending on the kind of steel, thickness, intricacy of contour, the

quality and finish desired, etc. Set-up and gas consumption tables are furnished, covering steel up to twelve inches thick or more. Reference to these tables provide reliable estimates on gas consumption and cost as well as actual cutting time. Tip sizes and gas pressures, which represent good cutting practice are shown in these tables. To assist in the accurate layout of templets, the approximate kerf allowance for the various tip sizes is also shown.

Cutting Costs Estimates.—Actual gas consumption costs can be estimated; other cost factors are handling, setting up time and overhead. Hourly overhead is known. Handling and setting up time can be readily determined from a study of the actual job. The sum of gas consumption costs, handling and setting up costs and overhead is the total cost of machine gas cutting.

With dependable estimating data available, work may be estimated on the basis of machine cutting and compared to present practice. Savings are usually apparent. Consider also the flexibility of the process, the ease and speed of accomplishment, and the dependability, quality and accuracy that machine gas cutting offers.

Years ago the gas cutting machine in a shop was a piece of equipment to take care of the odd job, now it finds itself in the production line and plant management will give careful study to its correct location. Consider the flow of work to and from the machine and don't overlook the all important matter of adequate handling facilities. Study the capabilities of the machines in use or under consideration and develop all the information possible regarding the regular and out of the ordinary jobs that may be accomplished with it.

The foreman in charge of cutting operations need not be an operator but the more he knows about good cutting procedure the more efficiency he can derive from his machine cutting equipment. Machine cutting tables should be conveniently located to the machine and readily accessible for reference. Once established for the economy and quality of work such tables should be adhered to, and estimated schedules may be met.

Cutting charts may be supplied by the machine manufacturer but oftimes certain work requires a deviation from such outlined tables. Mechanical gas cutting equipment is quite flexible in its adaptation to regular and specific work and, therefore, it is quite natural for certain industries to develop special charts for their work. The governing factors are economy, quality and mere severing operations as well as special procedure for certain alloys.

Accumulation of Data.—The individual in charge of the cutting department will do well to develop and record basic information on special work. Reference to such data upon a recurrence of such jobs saves time and improves cutting practice.

Information should be kept on all types of cutting and if possible the operator should be encouraged to keep a log book of his cutting activities. As time goes on a wealth of information will be gained from proper log book records, which should be checked, studied and recorded periodically by the department head

Cutting Procedure.—Cutting procedure on the more complicated contours involves correct starting point and direction of travel, proper support of the work piece and the scrap. The use of tie bars to preserve contours on critical sections should be employed and starting cuts inside the outer contour resorted to for the same reason. Cutting in two planes may be readily accomplished by simple jigs and should be encouraged to further reduce costs and add to the usefulness of the cutting equipment. Bevel cuts may be made on straight lines or irregular contours and double bevel cutting in a single pass is now available to industry. Flame piercing of starting holes in plates, slabs and forgings saves time over drilling, and should be controlled by outlined procedure to the operators. Preheating and annealing practice should be clearly outlined on the class of work done, correct control of this phase of mechanical cutting work is obvious.

Machine Cutting Tips.—The cutting tip is the cutting tool, keep it in as good order as the milling cutter, the drill or the lathe tools. You wouldn't blame the lathe if the tool was improperly set or ground and that goes for a cutting tip as well. Use the machine cutting tips in the hand torches when they show signs of affecting the quality of machine cuts. Some plants have a maximum time limit for which cutting tips are used on a machine after which they are replaced. They find it economical and maintain a better standard of quality by such procedure. All such control promotes a more orderly cutting department and results that are more dependable. The personnel feels the cutting department is being required to maintain a higher standard and the correct mental attitude is encouraged in the interest of efficiency.

Drawings and Templets.—The matter of drawings for hand tracing or templets for mechanical guidance deserves some consideration. It is our thought that the layout for templets and tracings should be prepared by the drafting department and sent to the cutting department. A qualified mechanic should then lay out and build the templet. When a templet is completed, tried out and proved satisfactory it should be marked by the builder to center the responsibility. The templet should be stamped or marked with the part number of the piece to cut, and also with the tip number, oxygen and acetylene pressure to use as well as the speed of cutting. The templet is a tool to the extent of a jig and should be cared for the same as a jig for future use. With the cutting information for the specific job recorded on the templet the operator loses little time in setting up and starting production.

The Engineering Department should be familiar with cutting tables and basic machine cutting data for estimating and layout. This will expedite matters in the cutting department.

Conclusion.—Why not think in terms of mechanical cutting and make a serious effort to keep up to the minute on what developments are being added to those you are already familiar with. You may not be able to use them all, but with certain information filed away in your mind you may be able to solve some knotty problem at some future time. If you do not use mechanical cutting at present inform yourself of its usefulness. Get acquainted with it as well as you can under such circumstances as will permit. Mechanical cutting is being done more and more. Really, the use of the process has just recently seriously interested industry. More machines will make their appearance; they will follow in a sense the machine tool development, that is special machines for special jobs. High production on certain jobs warrants such development and progress means constant improvement.

Mechanical gas cutting has an enviable background in up-to-date industry. The present stage of dependability and usefulness is the result of earnest effort to put to use a process that has progressed beyond the laboratory stage and proved its advantages over a period of time. It is so simple, so flexible, so economical, that compared with conventional standard practice, it antiquates production methods in vogue, revolutionizes shop practice and flings the door wide open to lower operating costs.

FABRICATION OF—Large Diameter Pressure Vessels

By A. KIDD†

THE PROBLEM

THERE is a demand for containers of larger and larger diameters. Recently an oil refinery wanted six coking vessels 16 feet in diameter and 60 feet long, and a low pressure evaporator tower 15 feet in diameter and 80 feet long. The specifications for these towers called for design and manufacture in accordance with the A. P. I.-A. S. M. E. Code, with the further requirements that all welded seams be X-rayed and stress relieved.

This demand was unusual in that it offered many problems in manufacturing and transportation unparalleled to date.

Because these vessels were too large for rail or boat transportation, they were sealed and put in the Hudson River at Jersey City, and towed over 3000 miles by way of the Hudson River, the Erie Canal and the Great Lakes, to Whiting, Indiana. Because the Canal would be closed in November, it was necessary that the date of shipment from the plant be closely adhered to.

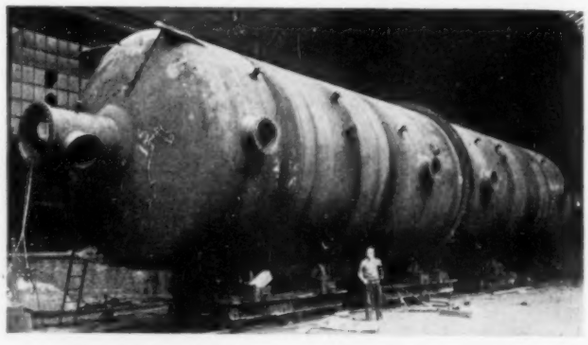


Fig. 2—The 230-Ton Evaporator on Special Trucks in the Plant

RAW MATERIALS

The first problem was the source for the chief raw materials: the plates and heads. In order to obtain an economical design, it was necessary to use the longest plates and largest diameter heads for material of this quality which had ever been produced. Each section contained one plate with one longitudinal weld and each head used on these towers was of the dished type and produced on the regular head spinning machine.

In ordering the steel, the time of the year that this order was placed had to be considered, on account of the shipping season, with further thought given to the fact that the steel mills at that time were being taxed to their capacity. Delays in receipt of material caused considerable concern regarding meeting the shipping date of the vessels.

PLANNING

A very carefully worked out plan had to be followed in the actual fabrication of these towers to avoid excessive handling and over-loading of expensive equipment.

WELDING

Each coking drum contained over 500 feet of welded seams, and the combined length of the main longitudinal and circumferential welds on the seven towers totaled approximately one mile. In order to insure the very minimum of repair it was necessary to insure the proper deposition of weld metal joining the various sections. This was accomplished by selecting the welding groove proved by experience to have given the best results. This groove was machined on all four edges of the plates used in the construction of these towers, and consisted of a $^{3}/_{16}$-inch landing for contact and with a $^{5}/_{16}$-inch radius at the bottom of the groove with a 5 degree taper.

The welding of these vessels was performed with three diameter rods, $^{5}/_{32}$ inch, $^{3}/_{16}$ inch and $^{1}/_{4}$ inch, with due consideration given to the voltage and amperage being used for the diameter rod, and the location in the welding groove, without sacrificing the ever important demand for speed.

WELDERS AND CHIPPERS

It was essential to select welders of the highest caliber. These welders were chosen because they had shown that they could produce welds which demanded a minimum of repair.

† The M. W. Kellogg Co.

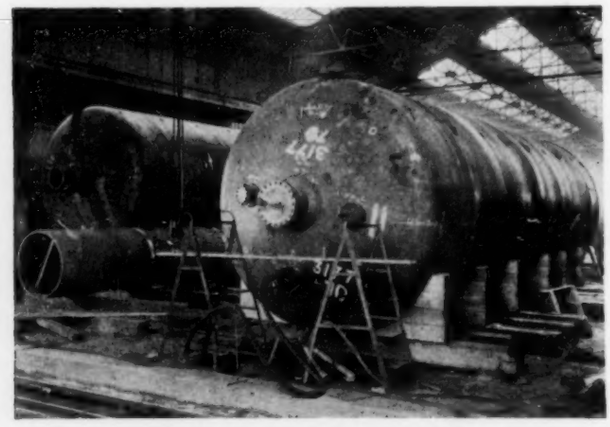


Fig. 1—Coke Drum Under Hydrostatic Test

Fig. 3—Coke Drums Lashed Together Being Towed Out of the Bay at Jersey City

Likewise, the chippers were selected from among those who were specifically trained in the inspection and removal of slag and defects in the manufacture of high-pressure vessels for high temperatures, over a period of years.

The work on these vessels continued for twenty-four hours a day. In order to make the work of the welders and chippers easier, special scaffolding was erected and a special lighting system was installed for the night shifts. In addition to this, special rotating trucks, capable of handling these extreme weights and large diameter vessels were constructed. Even though X-raying was used as a check, it was desirable to move these large vessels as little as possible.

In addition to maintaining a high standard of welding, it was extremely important to hold the ends of the individual sections round to close tolerance and shape so that the welded joints would match up to insure circular uniformity and meet the exacting code requirements.

STRESS RELIEVING

The welding on these towers was stress relieved in a specially constructed furnace capable of accommodating sections 16 feet in diameter. The temperature in this furnace is very closely controlled. Thermo-couples were placed on the vessels which indicated and recorded the actual temperature of the metal. The sections, having been stress relieved, were inserted in the furnace through an opening which was covered by a sliding door. Great care was taken in placing the sections into the furnace to prevent any sagging or buckling of these large diameter pieces of equipment during the heating operation.

X-RAYING

The main seams on these towers were X-rayed on a 300,000 volt X-ray machine with a technique specified by the A. P. I.-A. S. M. E. Code. This X-raying was carried on twenty-four hours a day, seven days a week. Over 1000 X-ray pictures were taken of the seams of the low pressure evaporator tower, alone.

HYDROSTATIC TEST

After completion, all the towers were subject to a hydrostatic test equal to a pressure obtained by using a full plate thickness in accordance with the Code rulings. Figure 1 shows one of the 16-foot coke drums being thus tested.

TRANSPORTATION TO HUDSON RIVER

Since the sizes and weights of these towers were in excess of those heretofore manufactured, many problems were encountered in handling the completed vessels from the shop to the railroad cars, for transportation to the water front. The 15-foot low pressure evaporator tower, when completed, weighed in excess of 230 tons. As stated in the early part of this article, clearances in and around the shop were so close that railroad officials were present watching every movement of the towers.

TRANSFERRING TO WATER

The unloading of the towers from the railroad cars to the water at the shipping terminal necessitated the services of one of the world's largest floating cranes, owned by Merritt, Chapman & Scott Corp. This crane is capable of lifting a 500-ton load, but this was the heaviest load it had ever lifted.

TOWING

The Moran Towing & Transportation Co., Inc., was retained to tow these unusual pieces of cargo to their destination.

Figure 3 shows four of the 16-foot coke drums lashed together with side bumpers and protecting heads, starting on their way. At Buffalo they were separated and towed three in tandem through Lake Erie, up Lake Huron and down Lake Michigan. The fourth coke drum remained at Buffalo to await arrival of the remaining two, for a duplication of towing and route.

The 15-foot evaporator tower was equipped with a great many more outside connections and nozzles and demanded special protection to prevent damage by floating debris, as well as rubbing or bumping locks or docks. The entire shell was protected with 14-inch square timbers, and the entire surface of these timbers was lagged with 4-inch thick boards.

Safe arrival of the towers was of paramount importance. Knowing rough weather was bound to be encountered, a further precaution was taken by protecting all openings, on the inside, with a cap, seal welded, around the inside of the vessel so that, should any unforseen impact break or damage a nozzle through the 4-inch wood lagging, the tower would not fill with water and sink.

The vessels were shipped with 25 pounds of air pressure so that by simply attaching a gage to a pet cock

installed for the purpose, the towing authorities could determine, by periodical inspections, whether any leaks had developed in the blind flange joints. This was to eliminate the necessity of removing any of the nozzle covers enroute to check the presence of water on the inside.

REMOVING FROM LAKE

Upon arrival of these towers at their destination, they were rolled out of the water onto the flat-cars which had been used at Jersey City, for transportation to the refinery. Many of the same problems of clearance at Whiting were encountered, and it was necessary to remove numerous obstacles along the route to be traveled.

At this writing all of these vessels have successfully reached their destination and are on their foundations ready for final connection with other pieces of refinery equipment. A very close inspection at the refinery site disclosed no damage whatever to these towers during their unusual trip.

Carbon Arc Welding of Hub Liners on Locomotive Driving Boxes*

Discussion by CLAUDE N. HOLWILL†

I WOULD first like to compliment Mr. Bennett of the Revere Copper & Brass Inc., for his splendid paper and with his permission, I would like to contribute to this discussion of some of our experiences in building up hub liners on locomotive driving boxes, using a 600-ampere unit, a one-inch carbon electrode and a special $^{7}/_{16}$-inch cast bronze rod.

This rod is essentially a bearing metal in that the composition of this rod is adapted from a standard crown-brass bearing metal, the analysis of which is as follows:

Copper 77, Tin 8, Lead 15 and Phosphorus 0.45

The addition of phosphorus is another necessary constituent acting as a deoxidizer and fluxing agent and aiding the flowing qualities of the rod. We arrived at this analysis because we have found that many railroads are looking for a rod that will have a high free lead content and that this free lead be kept in the weld deposit. On various tests we have found that with the carbon arc and the addition of phosphorus we could hold the lead content so that after welding, the weld deposit was approximately the same analysis as the original rod itself—the loss of lead being around a little more than one per cent.

The carbon arc welding of hub liners, when using a one-inch carbon electrode, should be done with a 600-ampere machine. It is also necessary to have a good water-cooled holder. In the actual welding operation 700 to 750 amperes at 55 to 60 volts should be used to get proper penetration and good heat distribution around the box. The correct manipulation of the carbon is a very important factor; it should be held in such a position that the bronze at no time will flow ahead of the carbon. The rod is cut up into 2-inch and $2^{1}/_{2}$-inch strips and placed on the hub liner surface which has already been surrounded by a properly shaped molding. The actual welding of the liner is then accomplished in a series of passes. The number of passes depends on how new or how old the box is.

The following figures are actual tests made on driving boxes welded with the carbon arc:

Number of passes	5
Actual welding time	32
Total time	77
Lb. of rod deposited	46
Square inches of welding	150

The following is an actual test made on a locomotive for milage:

The locomotive was in service for 50,000 miles. In for shopping, the wear on the boxes showed $^{1}/_{8}$-inch wear with no wear on the hubs.

If the locomotive was kept out for the full allowed tolerance, which is $^{3}/_{4}$ inch, this locomotive would have had around 250,000 miles.

We know the essential characteristics to be obtained in an alloy for bearings are analysis, strength, anti-friction qualities and temperature of running, therefore, one of the important qualities is its ability to operate in emergencies with no damage to speak of to either liner or hub. This can be accomplished by a homogenous mixture of copper, lead and tin.

In conclusion, we feel that the majority of railroads today are asking for a rod possessing good anti-friction qualities at high speeds that will withstand curvature impact and at the same time maintain these attributes under emergency conditions of poor lubrication.

* Paper by Mr. Bennett published in Oct. 1937 issue of THE WELDING JOURNAL.

† Applied Engineering Department, Air Reduction Sales Company.

1937 BOUND VOLUME

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SEVERE WELDING TEST

K. D. K. A. Antenna Tower

By G. A. HUGHES†

RADIO and structural engineers are greatly interested in the reconstructed vertical radiator or antenna tower of Westinghouse Station K. D. K. A. at Saxonburg, Penna. It is of uniform, triangular cross sections throughout its height of 710 feet above ground and uniquely constructed of solid structural rounds, shop welded into unit length columns assembled end to end in the field by means of bolted butt joints. A fair idea of the preponderance of welds may be gained from the fact that only about 400 heavy assembly bolts are used in the field whereas upward of 4400 electric arc shop welds were required to fabricate the tower.

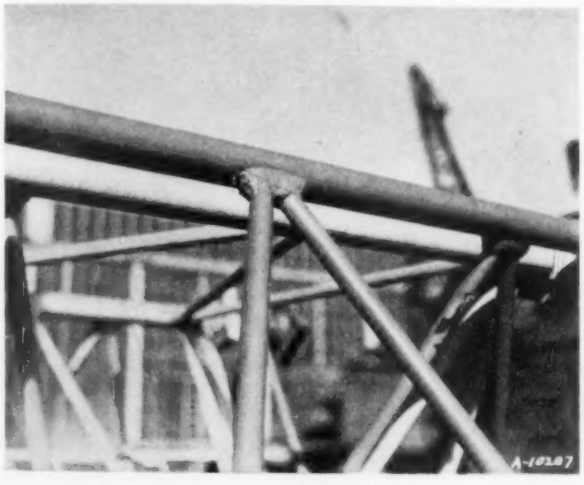
† Truscon Steel Company.

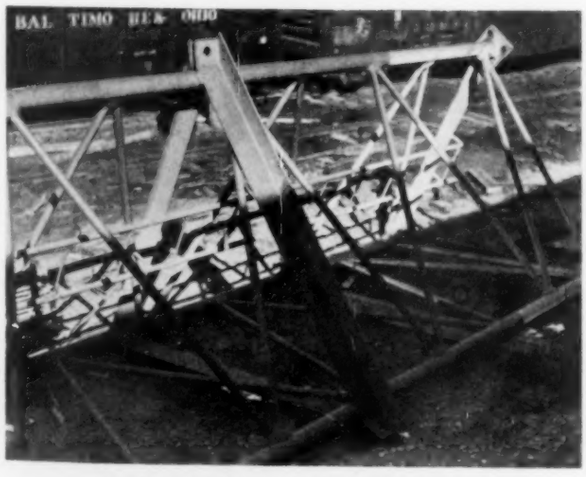
It is the tallest man-made structure ever fabricated by means of electric arc welding and includes many design features of interest to engineers. It is supported by two sets of extra high strength galvanized steel guys and designed to withstand 100 mile per hour indicated velocity wind from any point of the compass. It is insulated from ground at its base by a double cone insulator; also at approximately half its height to allow sectionalizing by means of a load coil.

The total weight of the mast proper is approximately 50 tons, half above and half below the sectionalizing insulators.

The electrodes used in shop welding were the heavy

Section of Tower Showing Welding on 3½-Inch Main Members

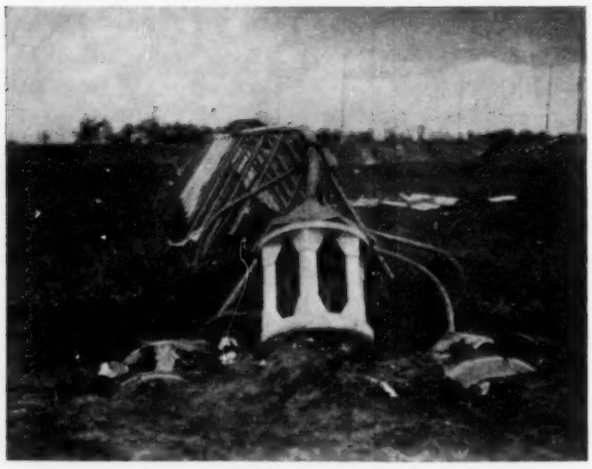




Section of Tower Showing Section Flange and Welding

Two Views of Upper Section of K. D. K. A. Station Tower After Falling 640 Feet. No Weld Failures

Lower Section of Tower



Upper Part of Tower Which Fell 640 Fee

fluxed type. Since some of the main members are extremely heavy, up to $3^5/_8$ inch diameter, closed welds incorporating fillets with radii up to $1^1/_2$ inches were used. It might be mentioned that the average material thickness is equivalent to that of a conventional angle structure designed for the same purpose consisting of angles with legs approximately one inch thick, and the unusual resistance to corrosion thereby offered reduces maintenance to a minimum.

The original tower, exactly the same as the rebuilt structure, had been erected to approximately 640 feet when a defective guy strand socket in one of the upper cables failed on October 30, 1936. The unbalanced load from the remaining two upper guys produced immediate failure of a second defective socket in one of the lower guys and the entire structure fell to the ground. The terrific impact of the fall from heights as great as 640 feet completely buried under ground 5 feet 6 inches triangular members as illustrated by the accompanying photographs. A remarkable feature was that over 200 feet of the lower portion of the structure was intact and due to the rigidity of the construction, no member was even slightly bent.

Main members up to $3^5/_8$ inches diameter solid rounds were completely severed at points away from web system welds and web members were likewise torn asunder without developing a single defective weld out of the total of some 3800 welds subjected to a test impossible to duplicate in any laboratory.

Competent and respected structural engineers still exist who are skeptical of welding, a typical reaction being as follows: "All of the testing and research has been of a laboratory nature, and not based on production welding."

We wish to direct the attention of this minority group of structural engineers and other engineers who share such views in opposition to welding to the K. D. K. A. antenna tower.

The fabrication of this mast was a production welding job, similar to 130 others of similar construction now in actual service. With further reference to the photographs, it will be noted that while many members were so twisted as to resemble pretzels and in several cases completely severed, not one weld failed.

3-Inch Round Main Member Twisted and Broken 8 Inches from Section Connection

Immediately following the disaster, the designs were checked by a number of capable engineers, several of whom were disinterested parties and the design as originally fabricated was approved for reconstruction with the single exception that proof-testing of guy assemblies was strongly recommended and the recommendation adopted. The replacement has been completed and it is confidently anticipated that no further trouble will be experienced.

Aside from the welding features herein discussed, it is felt that many engineers will be interested in inspecting the completed radiator. Saxonburg is a few miles south of Butler, Penna., and also easily accessible from Pittsburgh.

DEVELOPMENT IN WELDING

Large Structures*

By C. C. BRINTON†

TODAY with our greatly increased production many advantages of the fabrication of machine parts from rolled steel, flame cut to the required shape and welded together to form any desired shape becomes more apparent.

Without attempting to arrive at an exact comparison of the investment involved in the equipment required to produce parts of castings instead of fabricated rolled steel it can be readily seen that flame cutting and welding machines are much cheaper than furnaces and molding equipment. Also, just as important, the time required for the expansion of production facilities is considerably less.

When production is involved, time lost in replacing and repairing castings is as much of a factor as the cost savings to be found in fabricated construction. Where it was not uncommon to lose time due to scrapping or repairing from 5 to 15% of cast parts, this is now unknown if the part is fabricated.

Using rolled steel we can be assured that the material is free from sand, blow-holes and other imperfections and uniform in quality with constant physical properties.

It was necessary when using castings to carry a wide variety in stock representing a considerable inventory investment compared to stocking standard shapes of a limited variety and plates of the required sizes to take care of the demand. The time required to secure special sizes of plates which are only needed for special machine parts is still less than that required to make up patterns.

Developments which improve design or manufacturing methods are now carried out without delay as there are no patterns that must be changed or remade and no castings to be scrapped or used up for we are using a basic material.

When first changing many of our structures from cast iron or steel to rolled steel plates and shapes welded together to form approximately the same structure, it was extremely difficult not to produce the identical shapes which made up the individual castings. Although the foundry limitations were well known, the manufacturing and economical limitations for fabrication and welding procedure were not generally recognized with the result that some structures were produced that were not economical or practical for the fabrication.

There has been considerable progress since that time in recognizing that the problem is not solved by balancing the cost of steel plate at 2¢ per pound against a rough casting at 6¢. It is better to think of cast iron ready to pour and steel plates and shapes ready to be burned and formed to shape, as the raw material in each case and build up from there the final cost of each type of structure to be manufactured.

Fig. 1—Assembly Fixture for Welded Rings

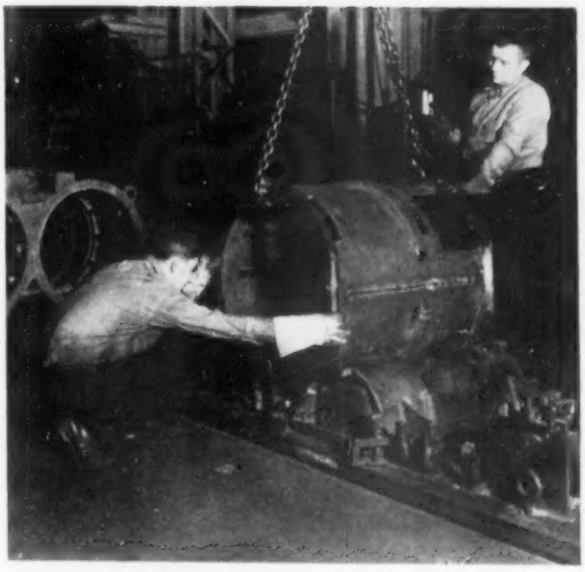


Fig. 2—Assembly Fixture for Twin Motor Frame

The available shapes produced by the steel mills are basicly structural and were designed for building bridges, buildings, etc., but with careful selection of those suitable for machine parts and their application in the proper place in the part, many economical structures are now produced with a low scrap ratio.

Plates, however, are made commercially in a wide variety of sizes and thicknesses which can be cut and shaped to most any desired form to serve any application

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* Presented before Joint Meeting AMERICAN WELDING SOCIETY and American Society of Mechanical Engineers at Hotel Traymore, Tuesday afternoon, October 19, 1937.

† Assistant Manager, Generator Division, Westinghouse Electric & Manufacturing Company.

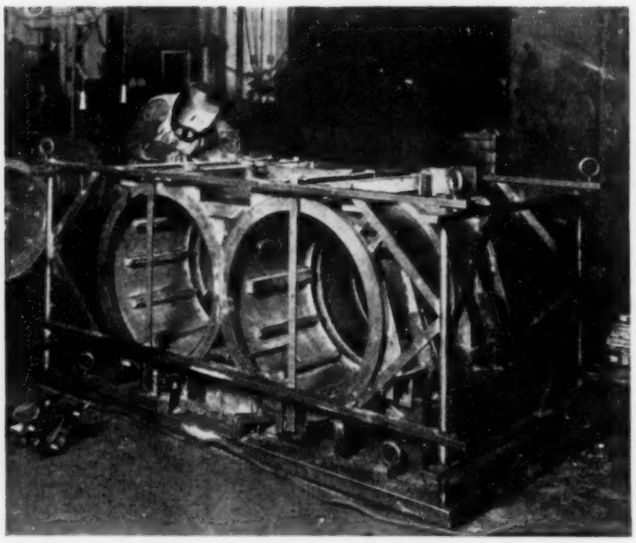


Fig. 3—Assembly Fixture for Twin Motor Frame

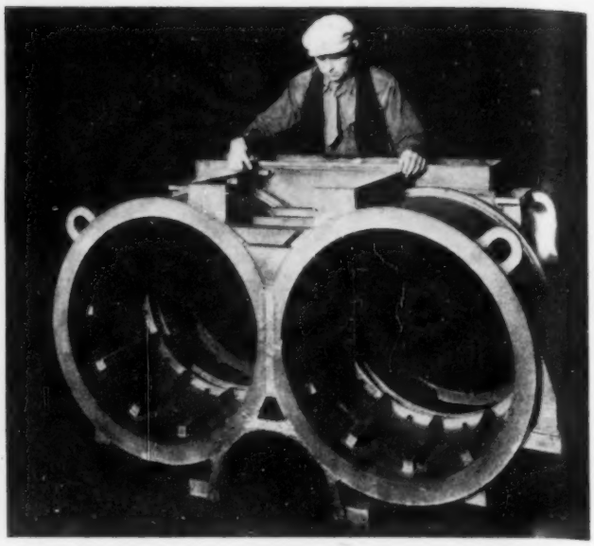


Fig. 4—Inspection of Frame After Welding and Stress Relieving

and used with the standard shapes when desirable in fabricating nearly all machine parts. The only limitation so far has been the size of the plates produced on the largest plate mills.

For some heavy sections it is desirable to use semi-finished material such as slabs, billets or blooms, although these are primarily intended for rerolling and consequently the tolerances are larger than on finished materials, they are suitable for parts that must be machined or where the larger tolerances are no handicap.

For certain parts of these structures it is economical, in many cases, to use steel castings welded to the structure when the sections are of such shape that it is difficult economically to make the entire part of plates and shapes. Although no definite rule can be established to cover such cases an example of the use of castings is for heavy cylinders as bushings in large gear cases.

The problem of arriving at the cost of any structure is not always clear cut unless there is a definite application of the scrap pieces left when the parts are cut or the structure be charged with the rough size plates and shapes and only credited with the scrap value of left-overs. With a reasonable activity, we have been able to establish a standard ratio to use for such material as follows:

Steel plates	160%
Steel slabs	110%
Angles, bearings, channels, etc.	110%

The results of the application of these ratios are shown for a typical month of 1937 in the table.

	Amount Received	Consumed	Scrap	Ratio
Plate	1,565,000	1,002,000	563,000	156
Slabs and Bars	356,022	317,572	38,450	112
Shapes	236,489	226,509	9,980	104
Total	2,157,511	1,546,081	611,430	140

In order to keep the amount of scrap within or less than the ratio, it is necessary to choose the stock sizes to suit those of the largest activity that are needed for the particular parts used and to order special sizes for large parts or those that require a large amount for a particular order of a size not carried in stock. Unfortunately, there are not enough small pieces required for our type of fabricated structure to allow the greater part of the scrap to be used and it requires close super-

Fig. 5—Frame Section Mounted on Automatic Welding Machine

Fig. 6—Welding Operation on Center Section of Large Upper Bracket for Waterwheel Generator

Fig. 7—Rotating and Tilting Fixture for Frame Section

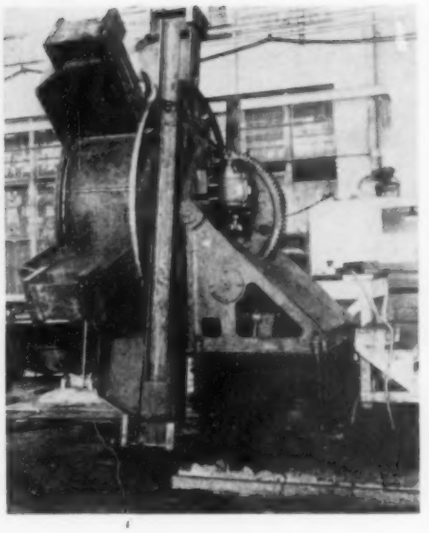


Fig. 8—Lower Thrust Bearing Bracket for Waterwheel Generator Mounted on Manipulator

vision to apply unused portions of plates to this activity economically.

The supervision is most important at the time the drawings are made since the scrap ratio is generally determined by the design of the parts and the choice of plate sizes from which parts are cut. Also, it is possible in some cases to apply some of the scrap pieces to other parts of the structure if a careful layout is made of the cut-out pieces.

The burden of carrying a great many irregular shaped pieces for an indefinite time in the manufacturing development for possible application is generally too great and these pieces must be scrapped at regular intervals or will be used up inefficiently.

The problem of assembling parts together in the minimum time and with sufficient accuracy that excessive weld material will not be needed, can only be solved by cutting and forming the pieces to exact size and shape with weld preparation carefully done. Pieces that leave large gaps between parts or require extra cutting by hand during assembly cause more lost time and extra welding than any other condition met in fabrication.

In order to avoid this condition, careful layout before burning, using sheet steel templates where enough pieces of the same shapes are required, is done for parts too large for automatic cutting machines. The layouts are prick-punched at a few places so that the cutting may be checked easily as the cutting progresses. In many cases it is possible to cut the part out of the large plates without cutting through the outside boundaries and avoid some of the distortion from the cutting torches.

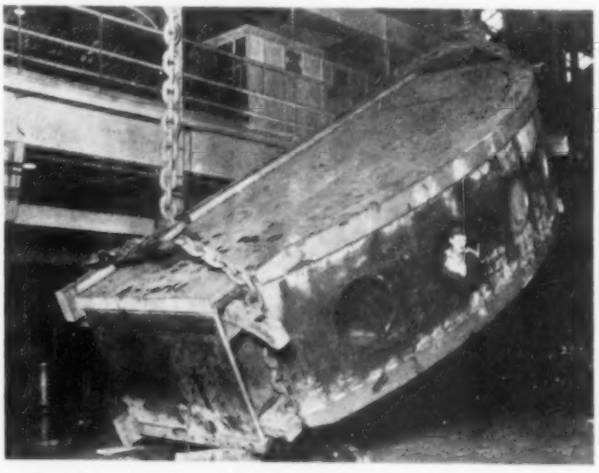
For the smaller pieces the cutting machines using paper templates or steel where the magnetic method is used, will produce very satisfactory parts and in many cases several parts of the same shape are produced at the same time with two or more cutting torches.

In order to arrange the work most economically the burning, grinding and trimming has been grouped so that all this activity is segregated from the assembly and divided into certain classes so that a group always does the same class of work. In like manner, the assembly before welding is divided into several classes so that each group handles only one class of work.

When assembling and tacking the large parts for final welding, steel surface plates are used that are sufficiently accurate to keep the structure level and allow them to be aligned properly. Enough tack welding is applied to hold the structure in shape and in most cases, to move it to another location for final welding.

The welding procedure is not the same with all structures but varies to suit the problem and usually is arrived at from experience with similar parts with a certain

Fig. 9—Positioning Heavy Press Bed with Overhead Cranes



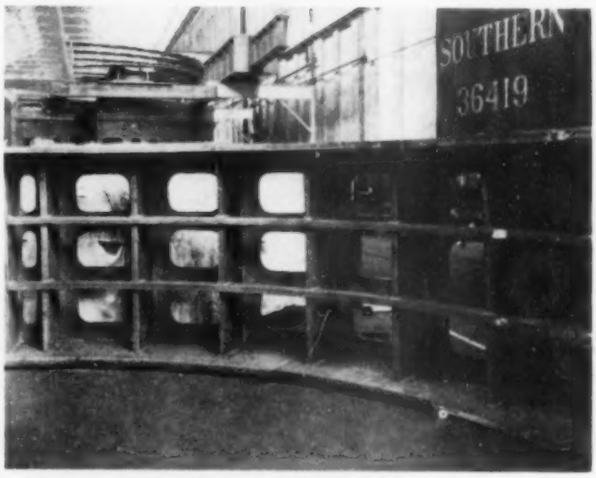


Fig. 10—View from Inside of Vertical Generator Frame

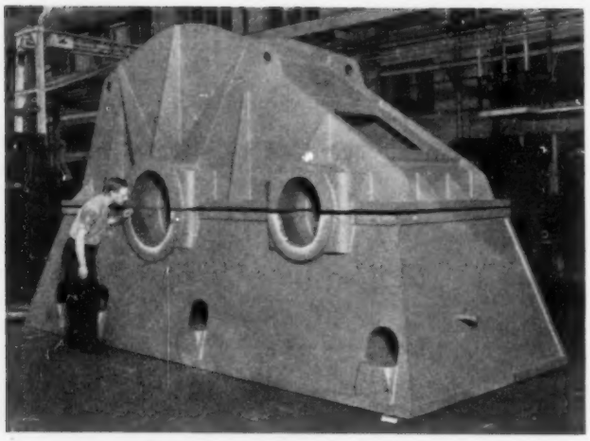


Fig. 11—Welded Reduction Gear Housing

amount of cut and try and checking during the actual welding.

Since one of the main elements in cost savings is in reducing the time required for machining and eliminating some of the machining operations, it is necessary to use fixtures for holding parts in place while assembling and welding and to avoid distortions by the proper welding procedure.

A typical example of the use of a simple fixture is shown in Fig. 1 where rings are welded together and held to a definite size; Fig. 2—setting motor frames in a locating fixture that is designed to hold the parts in alignment and shorten the assembly time and Fig. 3—tack welding the parts of the twin frame after they have been accurately located in the complete fixture; Fig. 4—checking the completed structure after the final welding and annealing.

When practical, it is desirable to design parts so that most of the welding may be done in the automatic machine and advantage taken of the lower costs and more reliable welding. The motor frame in Fig. 5 is an example where this can easily be done. It is more difficult to follow the same procedure for such parts as shown in Fig. 6 where the size is such that the welder must work on a platform. In this case the manipulator which handles the work has the controls mounted on the same panel with the welding machine controls and within easy reach of the operator so that the part and the welding machine can be operated from any position that the operator takes.

Many welding operations cannot be made with the automatic equipment and it is often desirable to provide handling fixtures to aid the operators to position the pieces for down-hand welding with a minimum of effort such as that shown in Fig. 7.

Figure 8 shows a large supporting bracket for a vertical generator that would be an awkward piece to handle for down-hand welding without equipment to position it readily.

The mounting of large parts so they may be handled safely and mounted quickly is the main problem to solve for the successful use of such equipment, as they are adaptable for both automatic and hand welding and the positioning can be controlled from any desired station within reach of the operator.

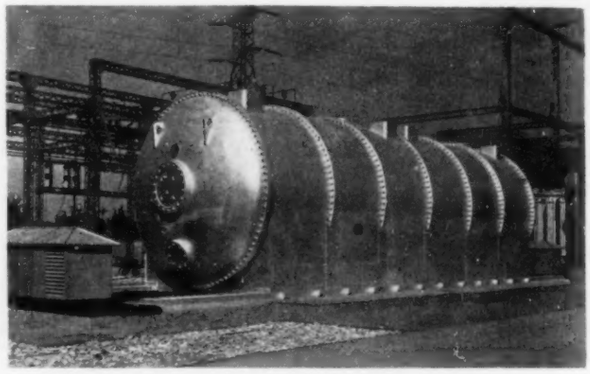


Fig. 13—Frequency Changer Installed Outdoors

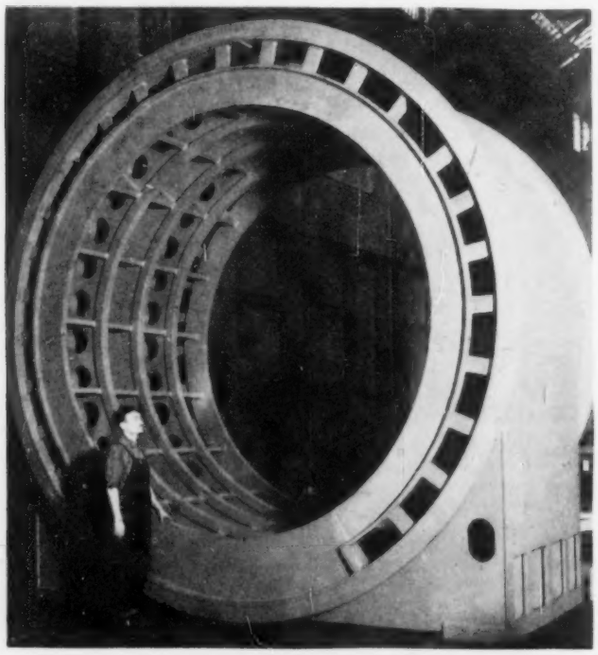


Fig. 12—Frame for Part of Hydrogen Cooled Frequency Changer

Many pieces that are of such size and shape that it is impractical to provide equipment to position them are moved with a crane from one position to another or held in place while welding as illustrated in Fig. 9.

Figure 10 shows one section of the frame of a vertical generator illustrating the progress made in reducing the number of pieces required to construct a suitable frame. The amount of weld metal to be deposited usually varies directly with the number of pieces to be welded together, therefore, this has influenced the design of machine parts to a greater extent than the placing of parts to facilitate welding and assembly.

Where weight limitations will allow, it is usually found more economical to use plates of sufficient size so that they do not require supports or braces for stiffness. In some cases it is cheaper to do forming of the lighter plates to provide stiffening sections rather than weld on extra pieces for that purpose.

Figure 11 shows a gear housing where steel castings and heavy plates have been used with a limited amount of bracing, but it is possible that further improvements can be made with a better understanding of all the economical problems involved. All structures, however, reflect in the design the type of tool equipment available in the manufacturing section.

The improvement in welding rods and the technique of application has made possible the easy production of large frame structures for the use of hydrogen gas as a cooling medium for generators, synchronous condensers

and frequency changer sets. These machines must not only be practically leak-proof with hydrogen, but explosion-proof if a favorable mixture of air and hydrogen should be present at any time.

By the use of double welds at the important points where they may be checked for leaks by introducing air pressure between welds, leaks are repaired as each weld is completed so that when the final structure is ready, only a few repairs are necessary. The final test requires that the completed frame will withstand a standard hydrostatic test for boilers and a time leakage test with hydrogen. Figure 12 shows the generator frame for

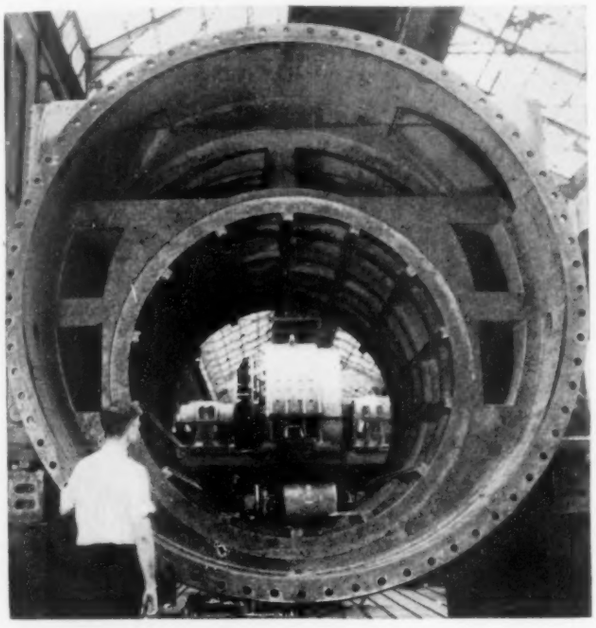


Fig. 14—Turbine Driven Generator Frame

the 60,000 kw. machine of a frequency changer set and Fig. 13 the completed set installed. Figure 14 is the frame of a hydrogen cooled turbo generator showing the use of a ventilation passage construction as stiffeners for the frame structure, and an unusual eccentric location of the stator laminations to allow the water coolers to be placed at right angles to the axis and above the frame center.

Figure 15 illustrates the adaptability of a welded construction for large D.C. armatures where the heavy arms are used for providing ventilation acting as blowers in forcing the air through the ventilating ducts in the laminations as well as mechanical supports for the structure. The steel ring end plates are shrunk on and doweled to the arms to provide a means for holding the laminations and taking the torque.

A number of rotor spiders have been made that are highly stressed in the rim section by rolling concentric rings welding them completely through at the ends, machining the two rings and the hub assembly so that

Fig. 15—Rotor for D.C. Armature

the rim is prestressed the required amount to avoid stresses in the welds on the arms. The rim welds are placed 180 degrees apart in the assembled spider which is shown in Fig. 16.

Although much progress has been made in constructing economical machine parts by welding, many more savings can be made in the development of better assembly and handling methods and the design of simpler structures than the actual application of the weld metal even though we are still making satisfactory progress in the art in developing welding rods that produce more satisfactory welds at greater speeds.

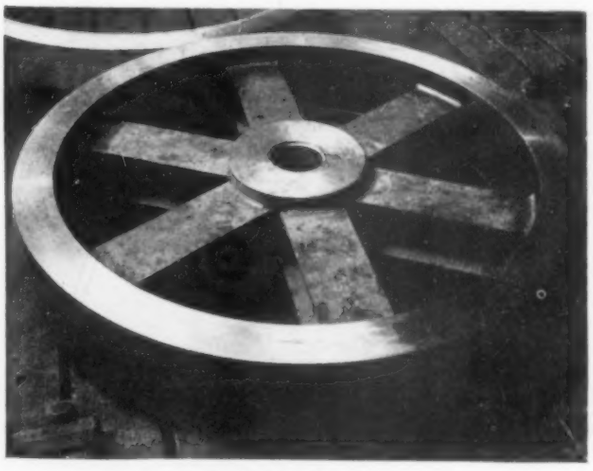
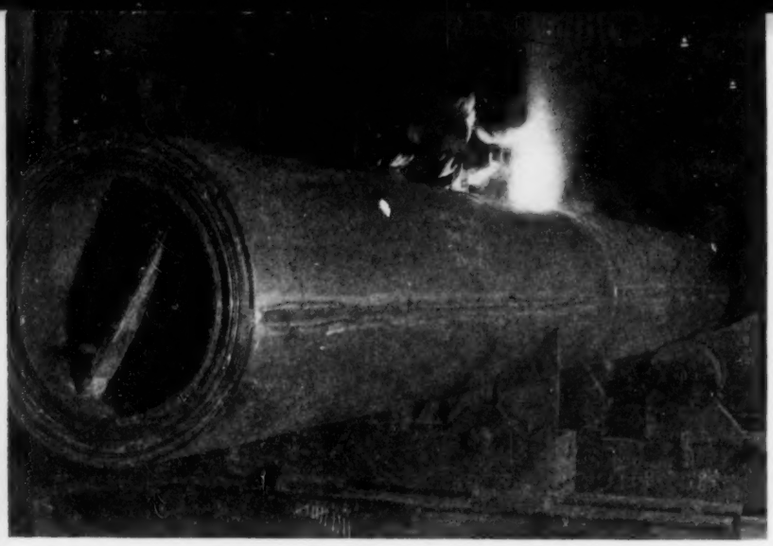


Fig. 16—Rotor for A.C. Generators



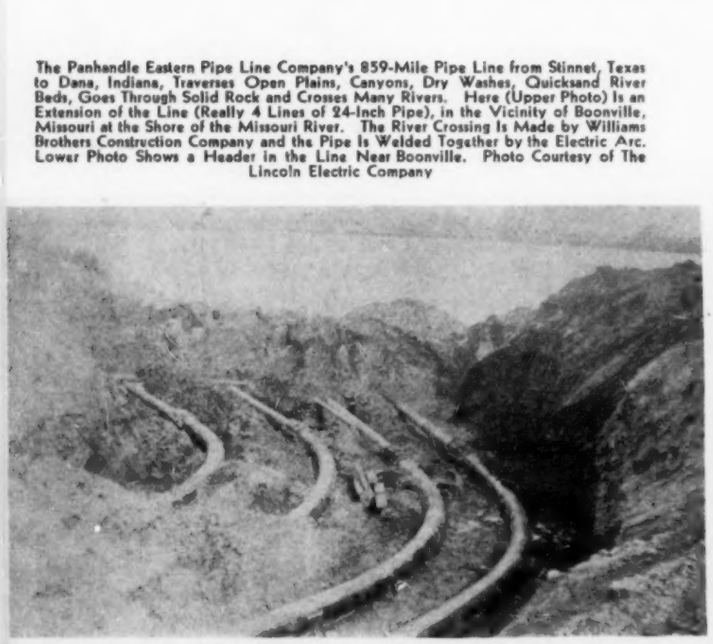
Multilayer Pressure Vessel in Course of Construction. This Construction Is Used for Very High Pressure Vessels of Small Diameter. Courtesy A. D. Smith Corp.

Lined Heat Exchange Shell for Corrosive Service. Note That Lining Is Attached by Means of an Automatic Welding Machine. Courtesy A. D. Smith Corp.

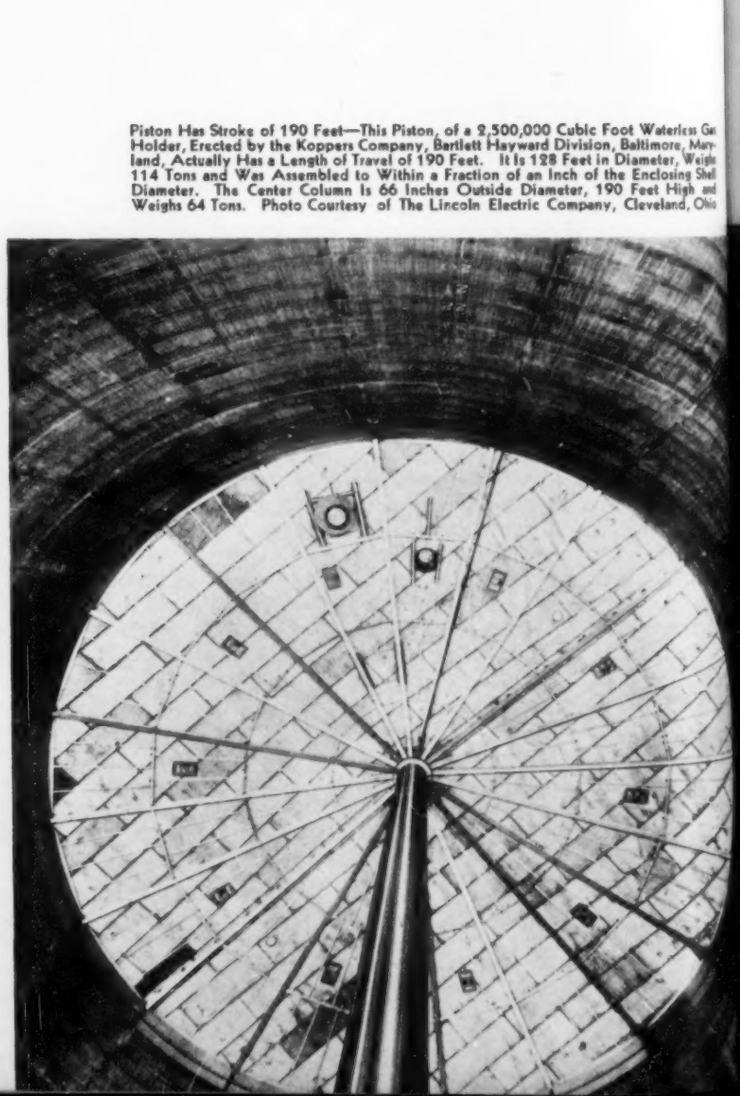
A Chem

SOME RECENT WE

The Panhandle Eastern Pipe Line Company's 859-Mile Pipe Line from Stinnet, Texas to Dana, Indiana, Traverses Open Plains, Canyons, Dry Washes, Quicksand River Beds, Goes Through Solid Rock and Crosses Many Rivers. Here (Upper Photo) Is an Extension of the Line (Really 4 Lines of 24-Inch Pipe), in the Vicinity of Boonville, Missouri at the Shore of the Missouri River. The River Crossing Is Made by Williams Brothers Construction Company and the Pipe Is Welded Together by the Electric Arc. Lower Photo Shows a Header in the Line Near Boonville. Photo Courtesy of The Lincoln Electric Company



Piston Has Stroke of 190 Feet—This Piston, of a 2,500,000 Cubic Foot Waterless Gas Holder, Erected by the Koppers Company, Bartlett Hayward Division, Baltimore, Maryland, Actually Has a Length of Travel of 190 Feet. It Is 128 Feet in Diameter, Weighs 114 Tons and Was Assembled to Within a Fraction of an Inch of the Enclosing Shell Diameter. The Center Column Is 66 Inches Outside Diameter, 190 Feet High and Weighs 64 Tons. Photo Courtesy of The Lincoln Electric Company, Cleveland, Ohio



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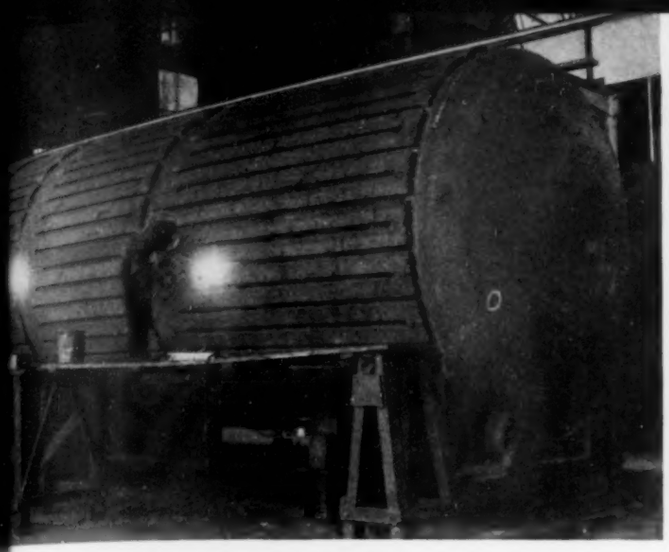
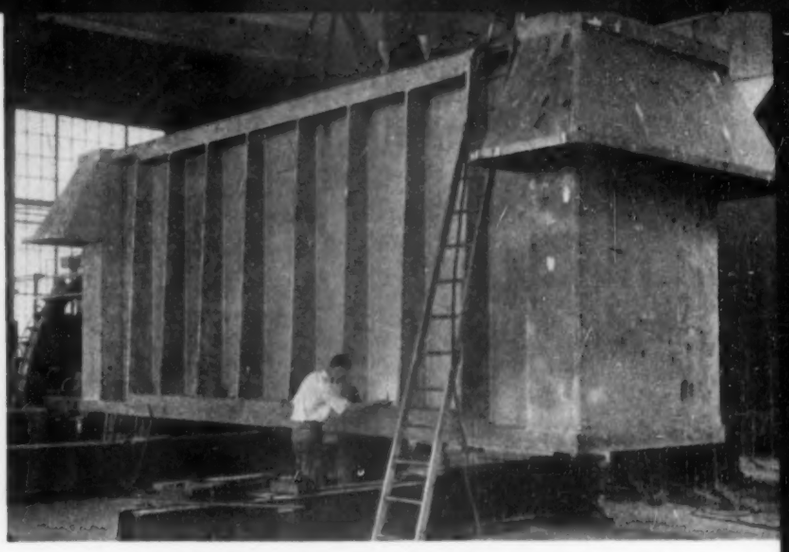


A Chemical Vessel with Outside Cooling Coils in the Course of Construction. Courtesy A. O. Smith Corp.



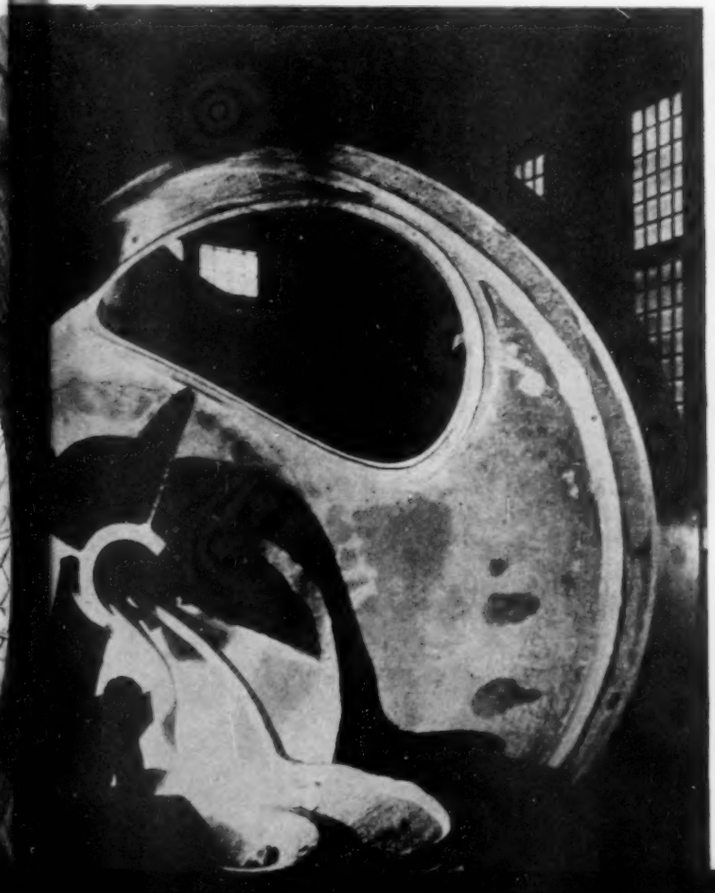
Welded Bed for Record Size Press. Note 11-Inch Thickness of Bed Plate. Courtesy A. O. Smith Corp.

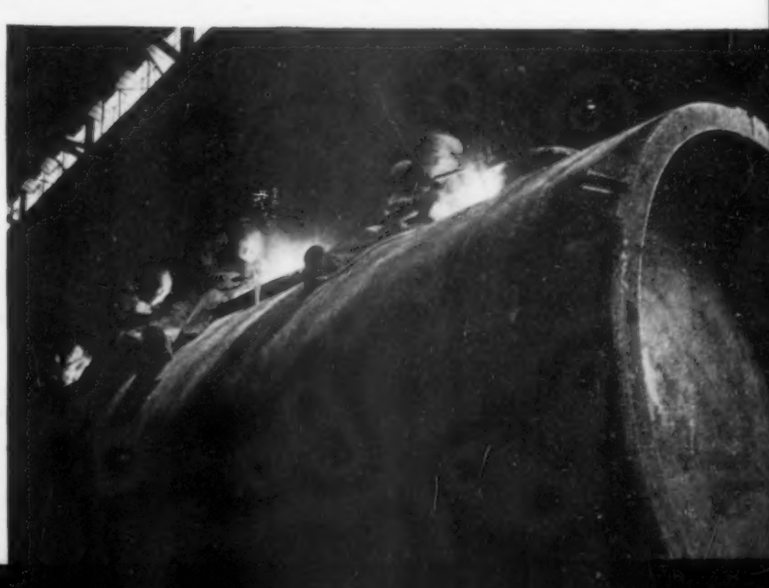
WELDING APPLICATIONS

Three Men in a Tub—These Hooded Workers in the River Works of the General Electric Company, at Lynn, Mass., Resemble Creatures from Another World as They Weld a Huge Low-Speed Marine Reduction Gear. Electric Arc Welding Is Playing an Increasingly Important Part in the Fabricating of Many Products, Large and Small.

Absorber Vessel—More Than 1000 Lineal Feet of Welding Was Required to Fabricate This Absorber Designed for Use in Treating Oil. It Is 8 Ft. in Diameter at the Bottom, 7 Ft. in Diameter at the Top and 58 Ft. 10 Inches High. The 1 1/16-Inch Flanged No. A-70 Steel Bottom Section Required 10 Beads of Welding. The 15/16-Inch Flanged No. A-70 Steel Top Required 8 Beads in All Roundabout and Vertical Seams. The Vessel Has 26 Flanges or Manholes Varying in Size from 8 to 24 Inches and Was Fabricated by the Tulsa Boiler and Machine Company. Courtesy Westinghouse Electric and Manufacturing Company

Appearing as Some Species of Octopus, It's Tentacles About to Imprison a Victim—This Strange Looking Object Is a 3-Foot 4-Inch by 5-Foot 4 1/2-Inch Conical Type Plug Valve Receiving a Seat Ring by Electric Welding at S. Morgan Smith Company, Manufacturer of Turbines and Valves, York, Pennsylvania. Photo Courtesy of The Lincoln Electric Company





A New Welded Temple of Science

ARMCO'S RESEARCH LABORATORY*

MORE than 200 scientists from all parts of the country were guests of The American Rolling Mill Company at the dedication of Armco's colorful new research laboratories in Middletown, Ohio, on Friday, November 5th.

"Research is what keeps industry healthily dissatisfied with itself," was the keynote of the dedicatory address by Charles F. Kettering, vice-president in charge of research of General Motors Corporation, at the banquet that concluded the day's activities.

George M. Verity, chairman of the board of Armco, told his audience that "from the courage and brains of men who have refused to accept today's products as representative of 'perfection' has come the impetus that has given us the highest standard of living known in the world, and which has provided profitable investment for savings of the nation, and work and more abundant opportunities for millions of men."

Charles R. Hook, president of Armco, declared "the real goal of industry is to find new products for old and new uses, so that as industry itself grows, more people will have the jobs and the money to buy these new conveniences. How can we achieve that goal? Research is the key, industry the force that can turn the lock."

Dr. Anson Hayes, Armco's director of research, was toastmaster.

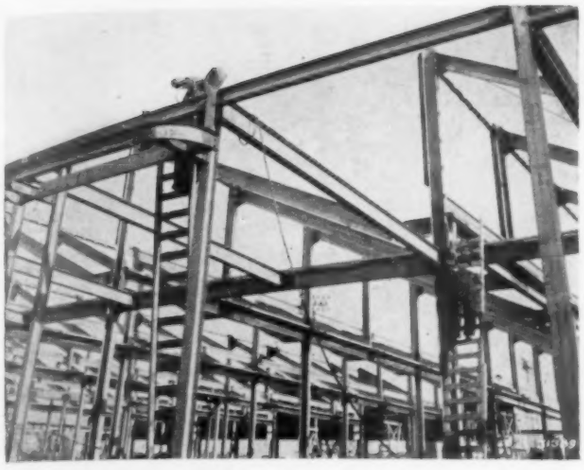
During the afternoon, guests inspected the new laboratories. A description of the unique building and a short talk by Mr. Kettering were broadcast over a nation-wide N.B.C. network of stations.

Research specialists have termed the new laboratories "the most modern in the industrial world." The building is tradition-breaking in design as well as in the combined application of new and old materials. Perhaps nowhere else in American industry are there laboratories that so completely illustrate a company's own progress in product development.

The building, costing $280,000, was erected by The Austin Company in cooperation with Harold Goetz, Middletown architect. A symphony of curves and angles accentuates the modern "streamlined" architectural design. Blended in colorful harmony on the exterior are porcelain enameled iron, stainless steel and glass block.

The single-story research building, with its sweeping lines, resembles silver-striped ribbons of yellow satin with alternate panels of jet and beading in between. It typifies modern industrial design and the rôle of sheet iron and steel in its application to construction. Al-

* From a News Release.



The Welder Helps Erect Armco's New Research Laboratory

though steel walls have been used in filling stations and other small structures, the Armco laboratories represent their first use on a large scale.

The building has a frontage of 255 feet and a depth of 175 feet, providing 43,500 square feet of floor space. It is a saw-tooth type with welded steel frame construction of new design. Not a rivet was driven in the structure.

A solid concrete wall, four feet underground and one foot above, forms the foundation. It is $9^1/_2$ inches wide at the base and tapers to $5^1/_2$ inches at the top. Structural steel is anchored to concrete piers.

Structural steel framework and bent beams for the saw-tooth roof were largely pre-welded in the shop to keep field welding to a minimum. Since most of the weight is carried in the center of the building, only 6-inch 15.5-pound H beams are necessary to support the exterior walls. Main saw-tooth columns are 16-inch, 36-pound wide flanged sections. The saw-teeth are spaced 30 feet apart and are supported by columns on 30-foot centers. The spacing, in addition to the elimination of trusses and other shadow-producing crossbars through the use of bent beams and welding, removes virtually all obstructions to the even distribution of light.

The building takes advantage of north light and reduces heating and maintenance expense, since the vertical surface of glass block has high insulating properties and constitutes a self-washing surface, in contrast to sloping saw-teeth where a 25 per cent loss of light is frequently encountered if the glass is not washed once a month or oftener.

Seven saw-tooth faces extend over the width of the laboratory section of the building. Each saw-tooth section has an area of 10 glass panels, with an area 10 feet 4 inches by 15 feet. The glass block, 5 inches by 8 inches and 4 inches thick, is supported in channels of the structural beams, with $^3/_4$ rod X-type wind bracings. The method of installation facilitates air-conditioning and eliminates the danger of leakage frequently encountered in sloping sash as a result of expansion and contraction.

Steelox metal roof panels are 18-gage galvanized iron, with a five-inch web on nine-inch centers, spanning 15 feet from girder to girder. For acoustical purposes, the metal ceilings of the offices are perforated with about ten $^3/_{32}$ inch diameter holes for every square inch of surface. The end of each panel is spot-welded to the center of the girder. Pitch of the roof is six inches for every twelve feet of horizontal run.

Acoustical cork inside the perforated ceiling panels rests on 1-inch metal chairs welded in the center and at the ends of each panel. On top of the cork, 26-gage galvanized corrugated iron sheets, with $^1/_2$-inch corrugations, run at right angles to the web members.

Ceiling of the chemical section is solid metal, with no perforations. The solid panels prevent gases from collecting under the roof of the building.

The roof is designed to carry a square foot load of 45 pounds.

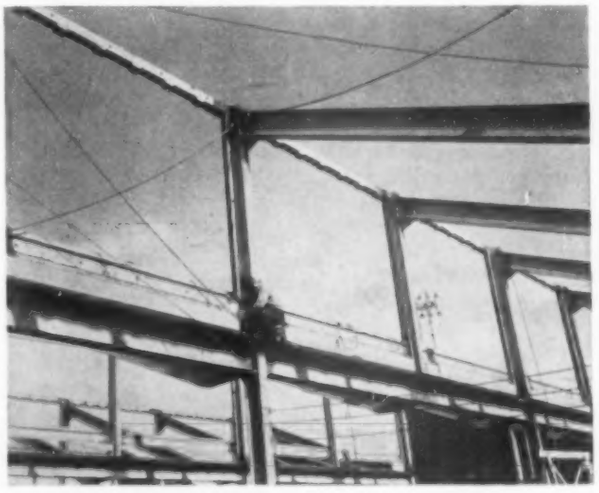
Exterior walls rest on a concrete floor slab which is integral with the building foundation. Three of the exterior elevations are faced with combinations of porcelain enameled iron sheets, stainless steel and glass block. They are formed with 13.6 pound 4-inch square metal tubing, which provides the skeleton for outside walls.

Horizontal metal tubes are welded beneath the window sills and above the glass block. Two vertical tubes in each pilaster are fastened to the foundation with anchor bolts. All tubes are welded to the structural frame.

Steelox channel sections, manufactured by Steel Buildings, Inc., an Armco subsidiary, form the nucleus of the wall sections. In all sections except at the glass block openings, 20-gage galvanized Steelox panels, with flanges facing inward, are bolted to the framework. Each section has a three-inch channel filled with an insulating material. The channels are covered with one-inch square continuous hollow metal furring strips, welded to the Steelox webs. Interior walls of the laboratory section are covered with 22-gage flat steel sheets, painted in two shades of gray.

For the exterior facings, porcelain enameled panels are fastened to the Steelox wall sections with metal girt strips formed in the shape of a hook. The water table base is of black enameled iron, which is concrete filled and has stainless steel trim at the joints.

Immediately above are cream-colored porcelain enameled iron panels, 2 feet $7^3/_4$ inches high. These were clipped to the girt strips and caulked. Four-inch bands of stainless steel, forming the cornice, belt course, window sill and head lintel above the glass block were also clipped on in similar fashion. Stainless steel one-



A Modern Research Building Is Fabricated by Welding

inch wide, also frames fixed plate glass windows inset in the glass block panels which, with the black porcelain pilasters, form a continuous band around the building. V-shaped vertical segment strips, also of stainless, provide contrast in the central two-story tower at the principal façade.

Above the second four-inch band of stainless steel are two rows of cream-colored porcelain enameled panels, each 3 feet $5^1/_2$ inches high. These sections, too, are separated by a stainless steel band.

The Steelox panels have been filled with an insulating material and covered on the inside with 18-gage walnut-finished furniture steel, except in sections where rough shop work dictated the use of painted sheet steel.

The rear wall, saw-tooth gables and most of the partitions in the laboratory section are of the insulated steel wall, developed by The Insulated Steel Construction Co. The wall is formed of two thicknesses of light gage sheet steel, filled with a special mineral product similar to mica which possesses high sound proofing and insulating qualities. The same material has been used in the flooring in the small second-story tower above the entrance lobby. It rests on a welded box-type floor 5 inches thick, which spans an area 18 feet wide.

The entire floor is concrete, covered with asphalt tile in the main office sections. All electric, telephone and other service lines have been placed underground in fiber ducts, which have been encased in the concrete floor. These are accessible through manholes every 200 feet. Controls are grouped, with a main distribution center at the switchboard in the center of the laboratory section.

Ventilation and atmospheric conditions are controlled by two air-conditioning systems, one for the research staff offices and one for the testing shops and laboratories. There are five units, two of which provide zone control for northern and western exposures. The laboratory section is conditioned by three units, each providing zone control in a self-contained group of rooms. These are supplemented by fume and heat exhaust systems in chemical laboratories.

Deep well water is used for summer cooling. It is pumped into the system at a rate of 400 gpm. and pressure of 50 pounds a square inch. Summer maximum temperature of the water will be 60° F. at the point of entrance to the building.

Fresh air intakes are set in the glass block sawtooth walls, and conditioned air is supplied to rooms through diffusing grilles placed near ceilings. In summer warm air is recirculated from rooms through grilles near the floor.

The office units are designed to maintain a summer dry-bulb temperature of 80° F., with a relative humidity not exceeding 50%, and a winter dry-bulb temperature of 70° F., with a relative humidity of 30%. Because of the highly insulated wall and roof construction, the relative humidity in winter is considerably above that for the average building.

There are twelve laboratories with complete facilities for specialized research.

They include equipment for setting up tests to determine and maintain the quality of all Armco products; welding methods with flat-rolled materials; forged steel car wheels; stainless steel; development of corrosion-resistant sheets and strip; iron sheets for porcelain enameling; high-finished sheets for deep drawing; sheets for electrical uses; development of zinc and other metal coatings for sheets; development of non-metallic coatings and the improvement of surfaces to hold these coatings; also for blast furnace, open-hearth and electric furnace experiments.

Clean Cut Interior Helps International Silver Company Triple Output

By A. S. LOW*

HUNDREDS of employees in the "making" department of one International Silver Company plant at Meriden, Conn. are now working in shadowless daylight in a new 43,000 sq. ft. plant, where welded rigid frame construction has been employed in a saw-tooth structure for the first time.

The new building was designed and erected by The Austin Company to accommodate continuous straight-line operations in a compact layout made possible by 100 per cent availability of space from floor to roof, which characterizes this new building type. Modern in design, it has continuous horizontal runs of sash on all sides.

"Tree form" welded columns which support the saw-tooth roof without any obstructing cross members have permitted the attainment of unusual lighting, which is uniform and without shadows, day or night. All the structural members were fabricated in the Austin shops at Cleveland and shipped direct to the site where erection was accomplished at a speed which attracted widespread interest among manufacturers throughout this busy industrial sector. Clearance ranging from 14 ft. at the top of the columns to 27 ft. at the peak of each sawtooth has facilitated the placing of machinery, conveyor equipment, special conduit channels and lighting fixtures.

The structure is the first to be built in a program tripling the capacity of one of the Meriden plants. International Silver Company operates 17 plants in United States and Canada and is known as the largest manufacturer of silverware in the world. Among its popular brands are the famous 1847 Rogers Bros., Wm. Rogers & Son, Holmes & Edwards, International Silverplate and International Sterling.

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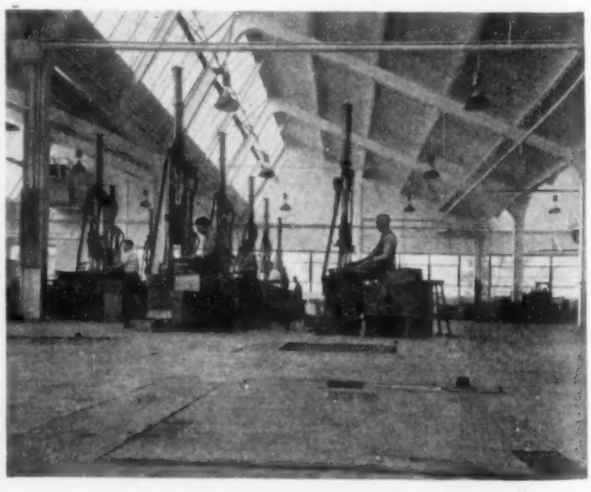
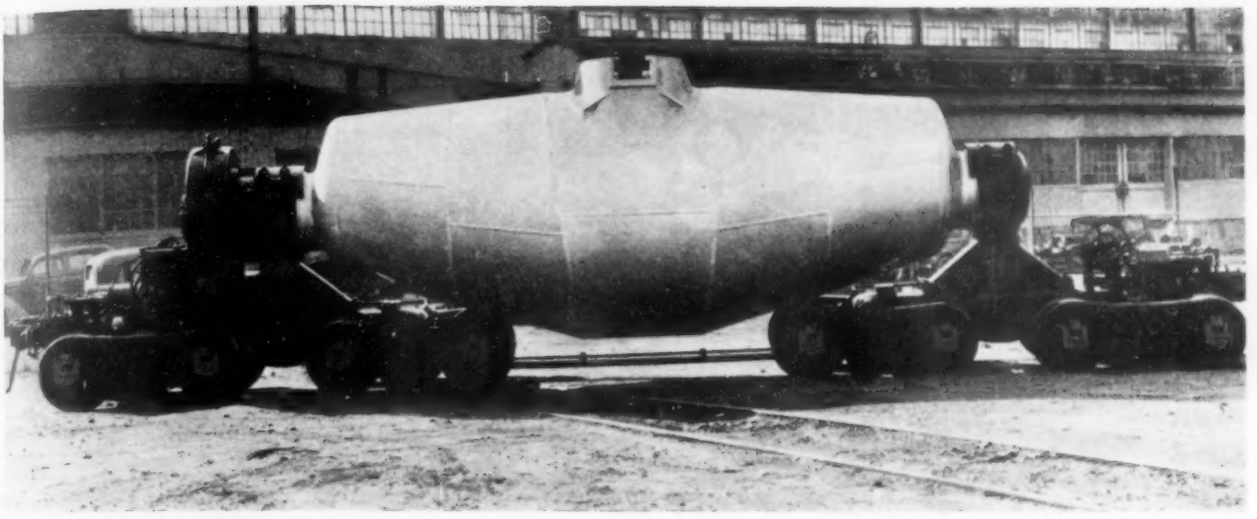
* Vice-President and Chief Engineer, The Austin Co.



A New Plant Erected with the Aid of Welding



New Self-Dumping Hot Metal Transfer Car Developed by Koppers Company's Bartlett Hayward Division at Baltimore, Md. The Ladle Has Greater Taper Below Its Axis Which Makes It Possible to Reduce Length for a Given Capacity and Pouring Spout Height

METAL TRANSFER CAR

By H. J. MANDEVILLE†

A NEW type of self-dumping hot metal transfer car has just been produced by Koppers Company's Bartlett Hayward Division.

It has been designed by Koppers engineers under the supervision of John D. Pugh, inventor of the original mixer type ladle. The first of the new cars has been built for Alan Wood Steel Company, Conshohocken, Pa.

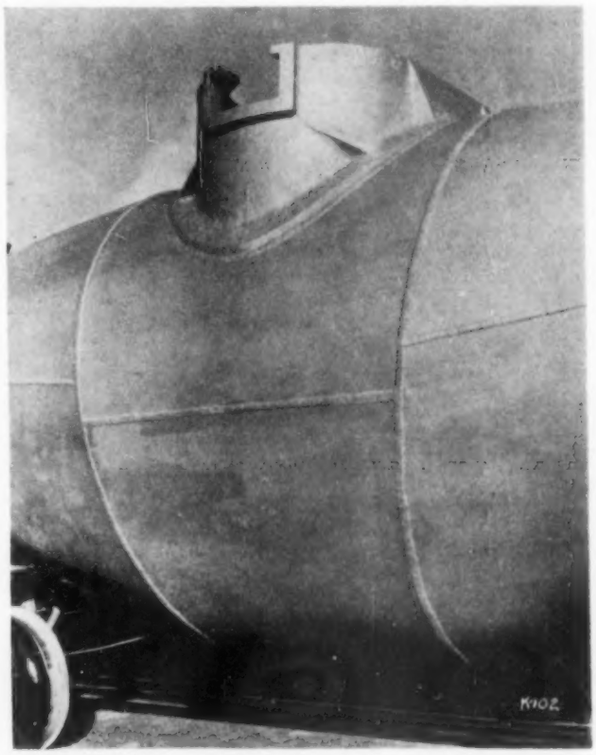
The car ladle is of the closed mixer type with a single central spout opening, but instead of being symmetrical about its axis of rotation, as ladles of this type formerly have been, this ladle has a greater taper below its axis than above. This results in reduced length for a given capacity and pouring spout height.

The ladle is all welded, having cast steel heads and pouring spout and a rolled steel shell. Welds between steel castings and rolled steel plates are stress relieved. This welded construction reduces weight and eliminates any hazard from loose rivets under repeated shock and strain.

Instead of elongated double-bearing trunnions formerly employed for supporting and rotating self-dumping mixer type ladles, the new ladle has trunnions which are relatively short and spherical in form at their extremities. These trunnions are supported in pedestals having concave spherical surfaces which, in cooperation with the spherical trunnions, form ball joint supports. No effort is made to keep the pedestal supports axially in alignment with the ladle itself. This eliminates any intermediate swiveled platform and permits mounting of the pedestals directly upon the car trucks. This reduces weight, and permits the trucks to assume any angular position required by track curvature or grade, by superelevation of rail on curves or low rail joints.

The mechanism for rotating the ladle for unloading also is mounted directly on the truck at one end of the car and is a new design. An electric motor drives through a pair of helical gears to a double worm gear reduction unit. This, in turn, transmits rotary motion to the ladle through a simple device which permits simultaneous angular and parallel misalignment without disturbance to the mechanical connection between the driving and driven elements of the car. While there are no loose fits or excessive clearances, no binding or cramping action results between the elements, either while rotating in any position, or while in transit.

The driving assembly is dust proof and all wearing



Closeup of the Welded Construction of the Central Portion of the All Welded Ladle, Showing the Butt Welding of Joints Between Rolled Steel Plates, the Cast Steel Pouring Spout and the Rolled Steel Shell

† Ketchum, MacLeod & Grove, Inc., 2000 Koppers Building, Pittsburgh, Pennsylvania.

parts are submerged in an oil bath. The hand wheel on the bearing pedestal may be quickly attached to the extended end of the motor shaft to rotate the ladle by hand in case of electric power failure. Plug-in connections for the motor are provided at each dumping station and electrical controls are so located that the operator can unload the car from a desirable point of observation.

These cars are mounted on four, six or eight wheel trucks, depending upon the size of the car and the wheel loadings permissible. The 125-ton capacity cars are mounted on two eight wheel trucks and, when carrying a charge of molten metal twenty per cent in excess of rated capacity, due to wear in the refractory lining, they weigh, together with the charge, approximately 529,000 pounds. Trucks can be equipped with plain brass journal or anti-friction bearings. Air or hand brake equipment, or both, can be provided.

The following general dimensions indicate the size and character of the car:

Length—center to center of couplers—48 feet $10^3/_4$ inches
Length—center to center of spherical trunnions—28 feet
Diameter of central portion of ladle body—9 feet 6 inches
Height of pouring spout above rail—12 feet $^7/_8$ inch
Driving gear reduction—13,272 to 1
Weight of car without lining—129,950 lb.
Approximate weight of lining—80,000 lb.
Molten metal capacity—125 long tons.

ARC WELDING—Simplifies Building Addition

By J. B. GEORGE*

TO PROVIDE sufficient area for mass production of industrial a-c motors at East Pittsburgh it was necessary to provide additional floor space. The additional space could not be acquired adjacent to the old motor manufacturing division, therefore, a new motor department was installed to permit building motors on a high-speed production basis.

To set up a highly efficient motor aisle with the sequence of operations in line and the materials and partly finished products conveyed on modern material handling equipment, an area of 197,000 square feet of floor space was required.

* Works Architect, Westinghouse Elec. & Mfg. Co.

Fig. 1—General View of Truss Design and Skylights Providing Excellent Natural Lighting

Fig. 2—Brackets for Sprinklers, Lighting, Steam Line and Power Feeder Supports Were Welded in Place

ARC-WELDED ADDITION ADDS 79,000 SQ. FT.

Two large buildings of steel and brick construction were available with a total floor space of 99,000 square feet that could be used for the new set-up. There was an open space fifty-eight feet wide between the two existing buildings that was used for a casting storage and equipped with an overhead traveling crane. By inclosing this space and removing the brick walls of the adjacent buildings, an additional 79,000 square feet of floor space could be obtained which would permit an ideal manufacturing installation where the operations were all on the same floor level.

When the overhead traveling crane was removed, calculations showed that the columns of the existing buildings would safely support a trussed roof over the open space between the buildings.

45 COMPOUND FINK TYPE TRUSSES

A compound fink type of truss was designed with a ten foot skylight along the center of each side of the roof for the entire length of the manufacturing space. The space on either side of the skylight was covered with a steel deck, 1/2 inch of insulation and waterproofing. Figure 1 shows that this arrangement provides exceptionally good natural lighting required for the detail manufacturing operations in small motor construction.

The structure for covering the open space required forty-five trusses on twenty foot centers with the necessary purlins and seat angles. Where the space was too great to span with one truss, columns were erected and the space was spanned with two trusses.

The trusses, columns and all detail structural parts were designed for welded construction which permits the use of lighter tension members, the exclusion of gusset plates, and simplifies the tool equipment necessary to do this work.

The trusses were made up of shapes best suited for welded construction. The top and bottom chords are H beams and the intermediate members are made of T bars and H beams, the tension members are flat bars. The shapes were chosen which were the most economical to sustain the required stress and the most economical to construct. By using flat bars for the intermediate tension members, the neutral axis of each member will meet and allow sufficient space for the weld metal.

SHAPES CUT TO LENGTH

After the designs were completed, the shapes for the trusses, purlins and columns were ordered from the mill cut to the required length. Where it was necessary to cope, or to cut a member on an angle a cutting torch was used. The only holes required were for use during erection.

For the erection of the trusses, seat angles were welded to the columns of the existing buildings, this method of construction eliminates the laying out and drilling holes as in riveted construction. After the trusses were in place, purlins were temporarily bolted at each end and the middle of the truss in order to keep the trusses plumb. The intermediate purlins were then erected in place and welded to the truss without the aid of erection bolts.

The columns and base plates were received from the mill cut to length and size, and the base plates were welded directly to the base of the column without the end of the columns being milled.

TRUSSES ASSEMBLED NEAR SITE

Assembly of the trusses was done as near to their erection site as possible. As there was overhead crane service in one of the original buildings, four arc-welding machines were connected up in this building and the first truss assembled on the floor from a layout. This truss was fastened to the floor and flat bars and angles were welded to it in such a manner that an assembly fixture for the following trusses was easily made.

Two of these fixtures were made to allow the fitters to assemble ahead of the welders and reduce the lost time of the workmen.

FIVE FEET PER HOUR WELDING SPEED

Each truss weighed 2200 pounds and required 295 inches of 5/16-inch fillet weld. The operators averaged better than five feet per hour welding speed using 5/16 covered electrode. This measure of speed includes all of the time lost in starting and stopping. In the matter of calculating estimated cost data for any welded structure it is vitally necessary to take into consideration not only the position of the members to be welded but also the size of each weld and the time required to move from one position to another.

In the case of built-up sections requiring either continuous weld or equally spaced sections or weld this speed might be easily doubled.

The errection crew normally consisted to two welders, two groundmen and a connector along with the engineer to operate the steam derrick. In the erection of a bouy, the welders, on each truss with an additional man to help, landed the purlins and made the welds while the ground crew were making the hitch for the next piece.

FIELD WELDING

Field welding consisted of 50 inches of 1/4-inch fillet weld connecting the purlins to the trusses and 12 inches of 1/2-inch weld fastening the truss and clip angle to one column. The other end of the truss rested on a lintel set in the brick work of the other building owing to the fact that these old buildings columns had not been set the same distances apart. It will be noted that with this setup there is no following up of the erection other than the inspector who not only checks the field welds but also is responsible for the shop welds as well.

Following the completion of the structural pieces by approximately five bays was the steel deck crew. This crew of three men erected this deck at a rate of 300 square feet per day per operator making three 1/2-inch tacks at top and bottom of each 24 inch wide sheet. This is done by using a current of 175 amperes and burning through the decking material and then fastening the edges of this hole to the purlin. It has been found that this method of application of steel decking materially improves the stability of the roof and also strengthens the structure against horizontal stresses.

SKYLIGHTS WELDED SUPPORTS

The supporting members for the skylights were made from "2 x 2" Tee bars with special clip attachments. These bars were erected with a crew of four men. Two welders and an erector making up the top crew and a helper to aid in their raising. This crew was able to erect and weld in place 800 square feet per man per eight hour day.

In completing the building, arc welding was used to advantage in the mounting of brackets for the sprinkler piping, the lighting brackets, power feeder supports and in the connections on the 150 pound process steam line, Fig. 2.

530,000 POUNDS STEEL: TON OF WELDING ROD

The total floor space provided by this project is 197,000 square feet, of which 55,000 is new. The total steel used, not including the roof decking and skylight bars was 520,000 pounds, or an average of 10.4 pounds per square foot. The total quantity of welding rod was 2250 pounds.

There are many advantages to be gained by the use of welding, but in order to realize them fully the designer as well as the contractor must judiciously select sections. In this way a building may be completed that uses the full weight of the members to the greatest possible advantage.

BUTT-WELDING OF RAILROAD RAILS*

By R. R. CUMMINS†

WELDING in connection with track maintenance is playing a most important part in prolonging the life of rail, frogs, crossings, switch points and numerous other items which go into track structure, and the practice is rapidly expanding. Prior to 15 or 20 years ago, maintenance of frogs and crossings consisted of tightening and replacing bolts and when worn beyond allowable limits they were taken out and scrapped.

The railroad with which I am connected, realizing the advantages to be gained, was one of the pioneers, if not actually the first railroad, to adopt welding in place with portable welding outfit, as a means of building up battered rail ends, butt welding rails in street crossings and station landings, repairing frogs, switches, etc. From a beginning of one welding unit in 1917, we now employ eleven skilled operators and their helpers.

There has been marked improvement in the methods now employed compared with what was done in the beginning. Increased metallurgical knowledge, improvement in the quality of welding rods and torches, better adapted to the work, as well as the experience gained by welding operators. After all there is no substitute for the skill of the craftsman in making it possible to continue in first-class condition, and at reasonable cost, many parts of the track structure which formerly it was customary to scrap.

Butt welding of rail ends, which will be the principal topic of my remarks, is of more recent development. Confronted with the problem of economically maintaining good riding track in two tunnels on our Birmingham District, it was decided to experiment with welded joints. The tunnels in which the welding was done extend through Coosa Mountain and Oak Mountain, located about 21 miles east of Birmingham. Both tunnels are single-track, the former being 2431 feet long and the latter 1198 feet long.

*Read at the 38th Annual Convention, International Acetylene Association, Birmingham, Alabama, November 10, 11 and 12, 1937.

† Assistant General Manager, Central of Georgia Railway.

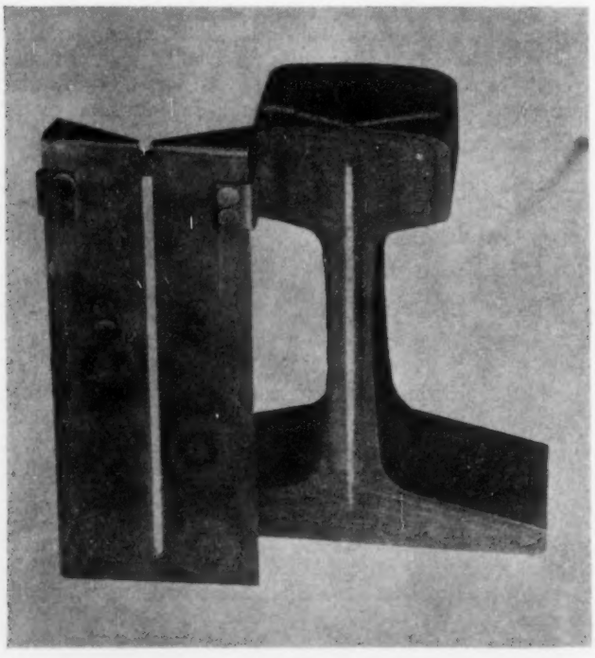


Fig. 1—Jig for Marking-Out Rail for Cutting Operations in Preparation for Butt-Welding

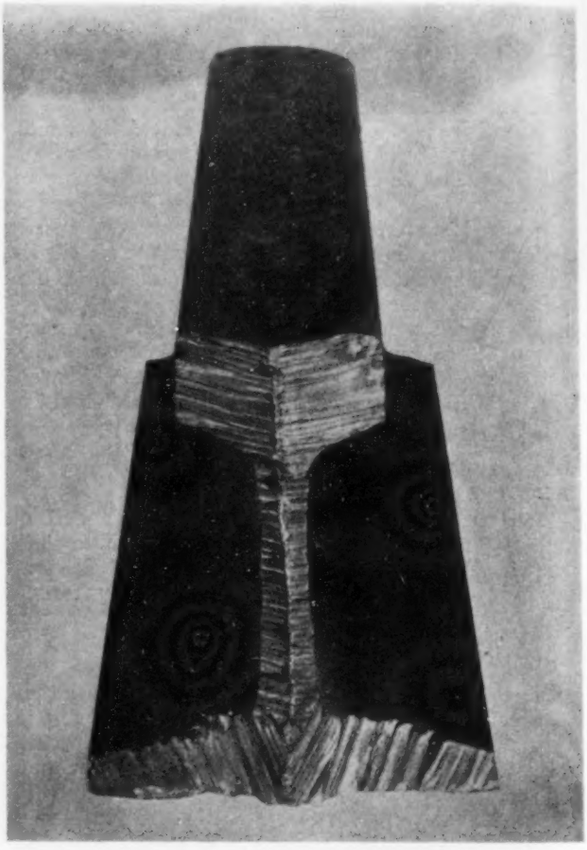


Fig. 2—Rail End Prepared for Welding

Because of limited overhead and side clearances and rock floors, it is practicable to apply only a limited depth of ballast under the ties, and this, coupled with the constant dampness from roof drip, and severe corrosive action of gases on bolts and angle bars, resulted in low joints and severe rail batter, regardless of the efforts of track forces. As a consequence, the service life of the rail and fastenings was limited to about 3 years and riding conditions were never comparable with track in the open.

To improve these conditions, new 90-pound ARA rail was laid in these two tunnels during August 1930, butt-welded on the outside in lengths of 429 feet and pulled into the tunnels by a locomotive, where the sections were joined by welds into continuous rails.

As a special precaution, all of the welded joints were fitted with second-hand 100% four-hole 90-pound joint bars, and the joints fully bolted, making it possible to

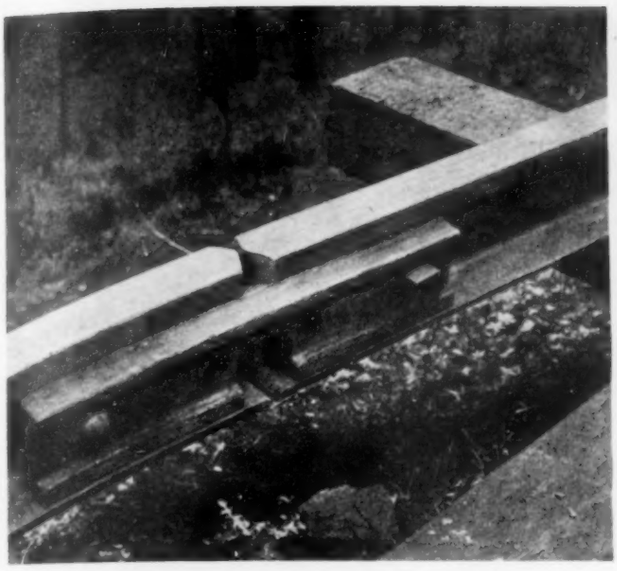


Fig. 3—Joint Prepared for Welding with Angle-Bar Jig and Backing-Up Plate

Fig. 4—Welding the Base and the Flange of the Rail

derive the value of the continuously welded rails without concern for the safety of the track structure.

Tests showed the range of temperature within the tunnels as 73° F., so that no trouble was anticipated with the expansion and contraction of the long rails; 1/4 inch expansion space was allowed at the first joint at each end of the welded sections, but this proved unnecessary since there has been no perceptible movement of the rails.

The only work on the rails prior to butt-welding them was "V"ing the rail ends. This was accomplished with a cutting torch; the web and flanges of the rail base were beveled to form a distinct "V" at the junction of the webs and base flanges of abutting rails. The rail heads, on the other hand, were beveled downward from a point about 1/4 inch back from the end of the rail, except for a rib left in the center of the head to facilitate starting the head weld.

Welding was commenced at the center of the base, at the base of the web, with the rails tight together so that the temperature of both could be kept as nearly uniform as possible during the welding operations.

From the center of the base, the welds were extended outward on each side, completing the base weld, then carried up the web and halfway through the head. Using a different rod, as already explained, the balance of the head weld was then made, the top surface being completed last.

In this latter work, at the running surface of the rail the new weld metal was constantly peened as applied, using a 2 1/2-pound machinist's hammer. The final smoothing and finishing of the top was accomplished by holding a 3-pound flatter on the welded surface and striking it with an 8-pound hammer. After completing a weld, all excess metal on the fishing surfaces of the head, and on the web and base, was removed with a torch to permit a snug fit of the angle bars. All welding was done by two crews, each consisting of an experienced operator and an assistant. Each crew completed an average of 3.29 welds per 8-hour day.

The average amount of material used in making each weld was 2 1/4 pounds of steel, 80 cubic feet of oxygen and 70 cubic feet of acetylene.

The long welded sections were allowed 24 hours to assume the normal temperature within the tunnels before being laid in track.

Prior to rail replacement, the track was carefully overhauled, necessary tie renewals made and all irregularities in line and surface corrected. However, no ditching or ballasting was done. As an extra precaution, to retard corrosion of the new rail and fastenings, all of the exposed steel of the track structure, except the running surface of the rail head, was painted with a preservative coating, and this practice has been continued each year.

During March 1937, after 6 1/2 years of service, which was more than double the service obtained before welded

Fig. 5—Jig for Holding Metal Dam in Place for Welding Rail Head

Fig. 6—Welding the Head of the Rail

rail construction was adopted, it again became necessary to renew the rail, this being due to loss in section from corrosion which in some instances approximated 30%.

Proceeding on the assumption that longer life would be obtained with heavier rail, it was decided to use rail of 112-pound section, welded in continuous stretches.

Consideration was given to welding by other processes, but as satisfactory results had been obtained by the oxyacetylene method for butt-welding rail ends in 1930, it was felt that with added experience, improved methods, better welding torches and material, together with the use of grinding and surfacing machines not available during the first experiment, continuance of the oxyacetylene method was justified.

In carrying out this work, it was decided to thoroughly clean out the ditches, renew all ballast and replace the cross ties out of face. Straps, consisting of old, light angle bars, were applied to the 112-pound rail which would not contact its head or base, this being in the nature of an added precaution in the event of a broken weld.

Ditching and removal of the ballast was commenced March 15, 1937. The force employed consisted of an extra gang of one Foreman, Assistant Foreman and 26 laborers. Material to be removed was loaded on push cars equipped with standard ditching dumps. Motor car was used for hauling to the dumping ground.

The butt-welding of the rails, which was done at a convenient location on tangent track outside the tunnel, was commenced March 22, 1937. The rails, 39 feet in length, were placed on cross ties and lined up in four stretches of 16 rails each, the ends opposite each other, so that four joints could be welded without moving the welding apparatus. Three sets of Welders were used and, in addition, three Instructors were continually present, for the double purpose of instruction and assisting in the welding. The ends of the rails were "V" 'd with a cutting torch prior to welding by beveling the ball and web into a double "V" and the base into a single "V" in order that an equal amount of metal might be placed by the two torches while working simultaneously on each side of the rail. The ends of two rails were then placed together in a straight line and a pair of angle bars, having a portion of the web-cut out to allow welding space, were applied. This maintained perfect alignment at the rail ends during the welding process.

A $^{3}/_{16}$-inch steel plate, 2 inches by $5^{1}/_{2}$ inches was placed under the base of the joints for the purpose of preventing flow of the metal as well as giving added strength. The weld was then started on the plate across the base. After the base of the rail was welded the angle bars were removed and carried ahead for other welds. Two torches were used to work the metal into place, one on each side of the joint. Steel rods $^{3}/_{16}$ inch and $^{1}/_{4}$ inch in diameter were used. After the base and web had been welded, a 1 x $2^{1}/_{2}$ x $^{3}/_{16}$ inch steel plate was placed under the ball of the rail on each side and the head was built up on these plates, which prevented flow of the metal.

After completing the weld, the rail was heated by using two large tips, for a distance of 6 inches on each side of the weld and a metal trough 8 inches by 3 feet was placed around the joint and packed with ground asbestos to

Fig. 7—After Welding, the Joint Is Slowly Cooled in an Annealing Box Filled with Asbestos Fiber

Fig. 8—Finished and Ground Rail Butt-Weld

normalize the entire weld, which was allowed to slowly cool for about 30 minutes The joints were then dressed with a surfacing and grinding machine.

Half of the welded section necessary to extend through the tunnel was dragged in by a locomotive, necessitating the last butt-weld in the tunnel. The welded rail sections were laid on the old cross ties replacing the released rail, and when this was completed, renewal of the ties out of face was commenced. Due to train schedules, one gang did all of the track work at night, and in the interest of time a second gang was employed during the day to clean up and carry in material for the night gang.

Creosoted pine cross ties, 7 inches by 9 inches by eight feet, were used, carefully selected, pre-bored and sized. Tie plates, $7^1/_2$ inches by 11 inches, which had been previously given a thorough coating of NO-OXIDE, a rust retarder, were applied. After the welded rail had been laid it was also coated with NO-OXIDE on all parts, except the running surface.

The temperature, which was read twice daily during the progress of the work, ranged on the outside of the tunnel from 32 to 80° and on the inside from 34 to 66° F.

Until this year we had never attempted butt welding on high-speed track in the open, but recently we have experimented with a stretch on our line between Macon and Atlanta, the installation being of too recent date to arrive at conclusions. This section of welded track is of 112-pound rail, 2184 feet in length, 20% of tangent track and 80% on a two degree curve. This work was carried out in the same manner as has previously been described in the tunnels, with the exception that 8 inches by 12 inches double shoulder tie plates were used, fastened independently to the cross ties with cut spikes. No rail anchors were used in this welded stretch and permanent reference points have been established at various locations as a means of determining any movement that may occur.

PRODUCTION OF SHEET METAL

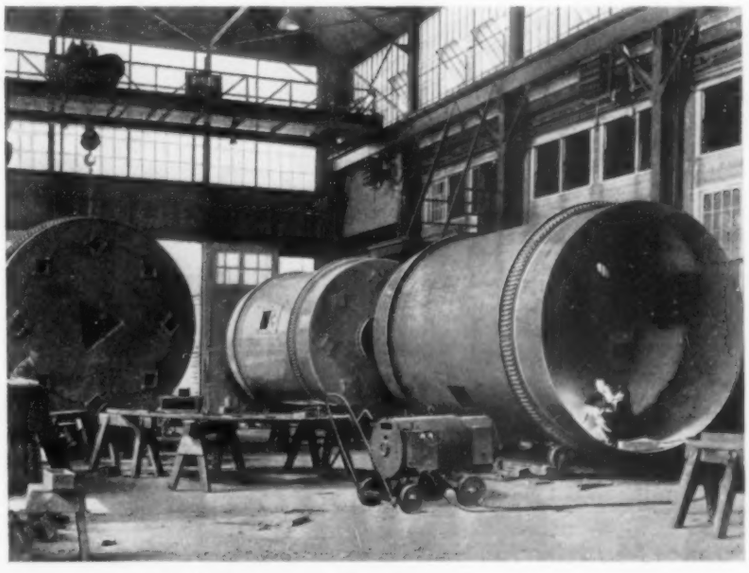
Brewery Equipment Stepped-Up by Arc Welding

By F. J. HIRNER†

The Galland-Henning Company of Milwaukee, one of the outstanding manufacturers of equipment for the brewing industry, has found that by changing from riveted to arc-welded construction they are able to materially step up their production schedules.

A concrete example of this is shown in their welding job in the photograph to the right. Shown here is a massive drum used for malt germination—with a capacity of 600 bushels of malt. Faced with an order of twelve of these drums at one time, the Galland-Henning Company found arc welding to be a great help in that it enabled them, without additional overhead, to increase production from three drums per week under riveted construction, to five drums per week by using arc welding.

Each one of these drums takes 400 lineal feet of welding. They are of rolled steel plates from $^5/_{16}$ to $^3/_8$ inches thick, with overall dimensions of 28 feet by $10^1/_2$ feet. Their massiveness makes arc welding even more valuable as it so greatly decreases the total weight of each unit yet maintains the proper strength.



It is also claimed that from a sales angle, these drums are much better in appearance than the old type—much lighter and easier to keep clean.

†Welder Division, Harnischfeger, Corp.

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WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

THE NEW YEAR

A Message from Our President

The beginning of a New Year is the time to look forward and to lay out plans in bold broad outlines. The details can be filled in later.

Our new cover shows the largest welded ship slipping down the ways to begin its useful career. The pages of the JOURNAL indicate milestones of welding accomplishments and new things about to be completed.

Ours is an industry built on the bedrocks of science and as we extend our structure we must ever seek to make sure that these extensions are safe, sound, economically justified and in accordance with good engineering practice.

In a Society like ours the keynote must always be cooperation and teamwork. Unlike an athletic team the number of players is not limited. There is room on the field for all. But there is a similarity with our athletic teams in that grand stand players while spectacular do not win the games. Our players in the research, membership, technical activities, section activities, publications, meetings, legislative, promotional and other branches can well feel proud of their work and accomplishments as they are all important and necessary for our well-being. The accomplishments of the Society at the end of the year must be measured as the sum total of these individual accomplishments.

As must be expected there are also a large number of members, who because of geographic location, demands on their time and for other reasons, cannot take an active part. There is plenty of room for these in the cheering squad and we all know that a few kind words go a long way toward encouraging the players. Every boost for the AMERICAN WELDING SOCIETY is another block in the structure of an international reputation as the world's leading technical Society in the welding field.

The year 1938 promises to be brimful of outstanding accomplishments for the AMERICAN WELDING SOCIETY. Spring will see our first Handbook. The first technical division will be created when the newly organized Automotive Welding Council is formally attached to the Society. Our first District Meeting will be held in March when our Pacific Coast Sections combine to hold a meeting during the Western Metal Congress. A new Building Code giving due recognition to the better grades of filler metal specification is now in the hands of the printer. A complete set of definitions are in process of completion. A revised specification for qualification of welding processes and operators is promised shortly. Several other new specifications relating to all types of pressure piping are in process of completion. It would take many pages to even briefly mention progress in membership, lecture courses, research, Journal, technical and a host of other activities. Elsewhere there is announced the appointment of a new coordinating and planning Committee on Outline of Work, and so it goes.

The AMERICAN WELDING SOCIETY is striding forward to take its place as one of the Nation's leading Engineering Societies. We are on the threshold of new and far reaching accomplishments. The President, other Officers and staff wish you all a Happy and Prosperous New Year.

P. G. Lang Jr., *President*

Western Metal Congress and Exposition

The Western Metal Congress and Exposition will be held in Los Angeles, March 21–25, 1938. The Pacific Coast Sections of the AMERICAN WELDING SOCIETY will take part in this Congress by having a cooperative meeting.

An unusually attractive program is being arranged. Some of these papers include Welded Piping for High Temperature and High Pressure Service; Design of Welded Connections in Building Construction, a Symposium on Welded Oil Casing Strings; Fabrication of Large Hydraulic Pipe; Stainless Steel Welding and Castings Combined in Corrosion Resisting Equipment; Resistance Welding Processes and Applications; Problems in Welding Light-Gage Metal; Welded Ship Construction, Hard Facing Materials; Welded Reinforcements and Attachments, their Application and Placement on Pressure Vessels; Helping the Small Job Shop Welders; Welding Cast Iron; Plate Fabrication in Machine Design; Stress Measurements in Welded Joints.

There will be business and entertainment sessions, inspection trip and ladies entertainment.

Dates of Other Conferences

The Texas Technological College, Lubbock, will hold its Welding Conference on Feb. 3rd and 4th, 1938.

The Welding Conference at The Ohio State University is scheduled for Feb. 24th and 25th, 1938.

Omaha Welding Company Conference is scheduled for Omaha March 2nd, 3rd and 4th. The annual conference of Iowa State University, Ames, is set for March 22nd, 23rd and 24th. Unfortunately, these dates conflict with the Western Metals Congress and conference being arranged by Los Angeles Section in Los Angeles but only a few people probably will be required to select one or the other and not able to make both.

The conference at the University of Kansas at Lawrence, Kansas, is set for March 31st and April 1st.

Purdue Conference Breaks Record

The 13th annual conference on welding at Purdue University, December 9th and 10th, showed 587 registrations, the largest number since Professor Hoffman inaugurated these conferences.

The new Indianapolis section of the AMERICAN WELDING SOCIETY held their December meeting as an informal dinner in the Faculty Lounge of the beautiful Memorial Union Building of Purdue, from 5:45 to 7 P.M. on the evening of December 9th. Every one attending the conference was invited to participate and nearly a hundred enjoyed this pleasant social hour together. Professor Hoffman who is a director of the section, presided and introduced every one from other sections. The managing director of the Society brought the group up-to-date with latest Society activities and reported on the Detroit meeting the night before.

The complete program of the conference is given elsewhere.

The manufacturers and distributors of welding equipment and supplies had a continuous operating exhibit and demonstration which was enthusiastically reviewed during the two days and included, among others, Air Reduction Sales Company, General Electric Company, Sutton Garten Company, Wayne Welding Supply Company, W. J. Holliday, American Optical Company, H. J. Bollman, National Cylinder Gas Company, R. Notvest, American Brass Company, Westinghouse Company, H. D. Adams Company, Hobart Brothers Company, Micro Products Company, Harnischfeger Corporation, Linde Air Products, Sellstrom Manufacturing Company, Aladdin Fluxes, Tanner and Company, D. Eaglesfield (Lincoln Electric Co. distributor), Hollup Corporation, Handy and Harman.

Committee on Outline of Work

The AMERICAN WELDING SOCIETY has always done an excellent job in cooperative research, and can be proud of its technical committees. Nevertheless, still greater opportunities present themselves.

At a meeting of the Executive Committee, AMERICAN WELDING SOCIETY, held November 29th, a Committee on Outline of Work was authorized. President Lang will shortly appoint this Committee.

The Committee on Outline of Work shall present a list of subjects for Committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention. It shall, in general:

1. Determine the need for the continuance of a committee.
2. Determine whether a committee's work shall be expanded.
3. Decide questions of jurisdiction between various committees, and prevent overlapping of committee activities.
4. Determine the need for new committees.
5. Before recommending the appointment of new committees, determine the probable expense to the Society in carrying through such work.
6. Estimate and set the probable time for undertaking and completing work.
7. Correlate and control the standardization work and the activities of the committees in the development of codes and other regulations. This applies to procedure and not to details.
8. Recommend the appointment of representatives of the Society to act in connection with the development of codes, standards, practices, etc. by outside parties.

In general, within the above limits, the Committee on Outline of Work is not required to do any work in detail, but it is to receive and consider suggestions and comments from all members as well as outside interested parties, and most particularly from Committee chairmen, as to expansion of existing work or the undertaking of new work. All such suggestions, when received by the Society, are to be acknowledged and referred to the Committee on Outline of Work.

In particular, present Committee Chairmen will be required to make a report to the Committee on Outline of Work, giving very briefly their accomplishments during the past year and their proposals for the continuation of the work which they are handling or the expansion of such work, or additions. All other members, or any interested party, may submit proposals or suggestions for work. These are to be, in turn, submitted to the Committee on Outline of Work.

After due and proper consideration of all of these circumstances, the Committee on Outline of Work is to present a properly coordinated program for assignment to existing committees or new committees to the Board of Direction, so that committees may be appointed or reappointed, and definite proposal of the work which they are to do briefly outlined to them. Furthermore, in the case of existing committees, the Committee on Outline of Work is to secure recommendations from the Chairmen as to the personnel of their committees, whether present committee members desire to be continued in their work or dropped, and whether any additional members are requested.

The whole intention is that the Committee on Outline of Work, without going into details, may review technical committee activities, and briefly head them up through the proper channels, in order that the Society as a whole may function as a technical society.

FUNDAMENTALS OF WELDING DESIGN

Evening Lecture Course

Arranged by
New York Section
American Welding Society
in Conjunction with
Polytechnic Institute of Brooklyn
at
99 Livingston Street
(one block from Borough Hall)
Brooklyn, N. Y.

Tuesday Evenings at 6:45
Beginning January 11, 1938

Free to Members—Non Members $5.00

JANUARY 11TH

Introduction to Proposed Course—Dr. Harry Stanley Rogers, President, Polytechnic Institute of Brooklyn—Introduced by R. W. Boggs, Chairman, New York Section.

LECTURE NO. 1—THE WELDING PROCESSES AND SYMBOLS, by Leon C. Bibber, Welding Engineer, Carnegie-Illinois Steel Co.

This lecture by Mr. Bibber will cover briefly the principal welding processes, a chart showing their subdivisions, the developments of welding symbols and their use, codes, specifications and qualifications of welders.

The lecture will be illustrated by lantern slides and will be supplemented by high-speed motion picture films to be furnished through the courtesy of the General Electric Company and The Linde Air Products Company. The latter film is entitled "Machine Cutting by the Oxy-acetylene Method;" the former film is a High-Speed Motion Picture of the Welding Arc at 2000 Exposures per Second.

JANUARY 14TH

OPEN HOUSE—"Open House" has become a tradition at the Polytechnic Institute of Brooklyn. Members of the Lecture Course are cordially invited to attend.

Exhibits of student design and research as well as features of scientific interests will be on display throughout the buildings. These exhibits are fascinating and inspiring in themselves as illustrations of the tools of the engineer and the scientist. They serve also to demonstrate the underlying theory and principles involved in the successful practice of these professions.

JANUARY 18TH

LECTURE NO. 2—METALLOGRAPHY OF WELDS, by Prof. O. H. Henry, Polytechnic Institute of Brooklyn.

This lecture will cover plain carbon steels, including, low, medium and high carbons. It will indicate the structural differences between welds, adjacent zones and parent material for each process of welding; the danger points and precautions to be used.

JANUARY 25TH

LECTURE NO. 3—SOME DESIGN PROBLEMS IN SHIP BUILDING, by J. L. Wilson, American Bureau of Shipping.

This lecture will include a number of examples in ship construction and how to go about designing for welding; the importance of procedure, sequence in welding; use of jigs and fixtures will be stressed.

FEBRUARY 1ST

LECTURE NO. 4—DESIGNING MACHINERY FOR WELDING, by Everett Chapman, President, Lukenweld, Inc.

This lecture will cover some of the fundamental concepts including, selection of material, use of gas cutting, elements of design for welding, precautions and step-by-step procedure in designing a specific machine; sequence of welding, jigs and fixtures.

FEBRUARY 15TH

LECTURE NO. 5—ELIMINATION OR REDUCTION OF DISTORTION AND RESIDUAL STRESSES IN WELDING DESIGNS, by G. E. Claussen, Instructor, Polytechnic Institute of Brooklyn.

This lecture will cover the theory of why residual stresses and distortions are caused; precautions to be followed; how they can be kept to a minimum and how they may be reduced. The significance and importance of residual stresses in certain instances will be brought out.

FEBRUARY 21ST

LECTURE NO. 6—DESIGNING WELDED STRUCTURES, by Gilbert D. Fish, Consulting Engineer.

This will cover the fundamental elements in design and a step-by-step procedure in designing certain structural connections.

Special attention will be given the design of multi-story buildings, on account of the inclusion of welding in the new Building Codes of New York and Chicago.

MARCH 1ST

LECTURE NO. 7—ALLOY STEEL WELDING, by Howard Miller and T. R. Lichtenwalter, Republic Steel Corp.

Welding low-alloy structural steels, with sound motion pictures and slides, by Mr. Miller. Problems in welding stainless and heat-resistant alloys, with slides, by Mr. Lichtenwalter.

MARCH 15TH

LECTURE NO. 8—DESIGNING WELDED PIPING SYSTEMS, LOW AND HIGH PRESSURE, by A. N. Kugler, Engineer, Air Reduction Sales Company.

This lecture will cover both Arc and Gas Welding.

MARCH 22ND

LECTURE NO. 9—DESIGNING PRESSURE VESSELS AND TANKS, by J. T. Phillips, Foster Wheeler Company.

Fundamental principles will be indicated and a step-by-step procedure in designing a pressure vessel for welding.

MARCH 29TH

LECTURE NO. 10—METAL SPRAYING, by J. Magrath, Air Reduction Sales Co.

Fundamental principles involved. Methods of metal spraying. Range of applicability.

SHEET METAL WELDING, by W. B. Nicholson, The Linde Air Products Company.

Jigs, fixtures, methods of overcoming distortion. Importance of accurate control. Difficulties encountered and how they may be overcome.

New York Section Lecture Course Committee Members

S. S. Scott, Chairman
G. E. Claussen
E. V. David
O. H. Henry
E. Vom Steeg, Jr.
Merritt L. Smith, Chairman, Subcommittee on Publicity
Charles Kandel, Chairman, Subcommittees on Membership and Finances.

New York Section Officers

R. W. Boggs, Chairman

Famous Motorship Sunk in Collision*

Original Electrically Welded Ship Proves Durability in 17 Years of Service

A recent casualty report recorded a collision off the west coast of Mexico between the auxiliary sailing ship Hidalgo and the motorship Cedros, as a result of which the latter sank. The port of registry of the Cedros was Ensenada and she flew the Mexican flag, being owned by Abalardo Rodriguez, former President of Mexico.

As such the Cedros was not well known, but she was, in fact, an outstanding vessel. During her career she had four names, and under the earliest of these she was a pioneer, being the first seagoing rivetless ship. That much stated, her identity will be quickly recognized by those who have followed the development of welding in shipbuilding.

The Cedros was originally, in fact, the Fullagar and was built in 1920 by Cammell Laird & Co., Ltd., at Birkenhead, her hull being electrically welded throughout by the Quasi-Arc process. The fact that she had seventeen years' service, which only came to an end because of a collision, is sufficient indication of the efficiency and strength of her construction, despite the fact that electric welding was then only in its very early stages of development.

Lap Welded

The plates of the Fullagar were not flush welded in accordance with modern practice, but joggled, giving the hull the appearance of a riveted ship with straight frames.

The Fullagar was, in short, a valid, full-scale experiment in electric welding because of the fact that no rivets whatever were used in her construction. In the early part of her life she carried steel plates from South Wales to Liverpool. Later she was engaged in coasting service in British Columbia, carrying cargoes of cement, and circumstances combined to make her experience as comprehensive as possible.

Plates Pushed Out

In 1924, she grounded on a sandbank in the River Mersey, and her bottom was set up about 11 inches over a considerable area. It has been recorded that it was faired simply by pushing the plates out again with jacks, no leakage from or cracking of the welding being found.

Before the repairs were effected, however, she had carried a cargo of coal to Belfast, where she delivered it without anybody suspecting she had been damaged at all. When the cargo was cleared out it was found that the bottom was set up as stated. It was proposed to take her back to Liverpool for repairs, but the underwriters said she was not worth repairing. Thus, there was the paradox of a ship having delivered her cargo in a satisfactory condition and yet deemed to be a constructive total loss.

* Oct. 22, 1937 *Journal of Commerce.*

S. C. Hollister Appointed Dean

The Board of Trustees of Cornell University at its first meeting in the administration of President Day held last week-end appointed Prof. S. C. Hollister dean of the College of Engineering effective immediately. Professor Hollister, who has been acting dean since the death of Dean Herman Diederichs last summer, was formerly Associate Dean of the College and, at the same time, was director of the school of civil engineering.

Coming to Cornell on July 1, 1934 from Purdue University, where he was professor of structural engineering, Dean Hollister has behind him a record of achievement as teacher and practicing engineer. He was educated at Washington State College and the University of Wisconsin. After practical work in Portland, Oregon, he became instructor in mechanics at the University of Illinois until 1917.

He was then appointed research engineer of the Corrugated Bar Company of Buffalo. During the war years, 1918 and 1919, he was with the United States Shipping Board Emergency Fleet Corporation. He holds the commission of Lieutenant Commander in the U. S. Naval Reserve.

Following his war service, he engaged in private practice in Philadelphia as a consulting engineer until 1930. From

S. C. Hollister

that time until he came to Cornell, he taught at Purdue.

He holds memberships in the AMERICAN WELDING SOCIETY, American Society of Civil Engineers, the American Railway Engineering Association, Franklin Institute and the Society for the Promotion of Engineering Education. He was president of the American Concrete Association from 1932 to 1934. He is a fellow of the American Academy for the Advancement of Science. He belongs to Sigma Xi, Tau Beta Pi, Gamma Alpha Sigma Tau, Chi Epsilon, Sigma Pi Sigma, Phi Kappa Phi and Alpha Tau Omega.

He has contributed to many publications, and since coming to Cornell has continued as consulting engineer on penstocks of Boulder Dam.

Calcium Carbide

The Permanent International Committee on Acetylene and Gas Welding, Paris, has issued four appendices to its International Standards on Carbide. The appendices deal with methods for controlling the size of carbide, sampling, determination of the acetylene output of carbide and determination of phosphorus in the acetylene.

Rail Congress

The Fourth International Rail Congress will be held in the second half of September 1938 in Dusseldorf, Germany. The following chief subjects will be discussed:

1. General Questions
2. Wear
3. Brittleness, Internal Stresses, Aging
4. Operating Results
5. Structural Problems
6. Welding

Manuscripts to be presented at the Congress should reach Dr. O. Petersen, Dusseldorf, Germany, not later than June 1, 1938.

Compressed Gas Manufacturers' Association

The Compressed Gas Manufacturers' Association, Inc., New York City, will hold its Silver Jubilee Meeting at the Waldorf Astoria in New York, on January 17 and 18, 1938. This meeting marks the completion of 25 years of energetic and constructive service to the compressed gas industry.

This Association for a quarter of a century has handled the technical problems of the many-sided industries which include the production and distribution of commercial gases, such as ammonia, sulphur dioxide, acetylene, carbon dioxide, oxygen, the liquefied petroleum gases and many others. It has taken a leading part in matters of safety such as safety in design of containers and methods of safe handling and transporting commercial gases in liquid form and under pressure. Many of the problems involving the technical and administrative questions important to the industry, such as testing, specifications, transportation, insurance and many other matters, have been effectively and constructively handled by the Association and its many operating committees.

New Welded Tanker

Philadelphia, Dec. 18th—Construction of a second 18,500-ton welded tanker for The Atlantic Refining Company has been started by the Sun Shipbuilding and Dry Dock Company, Chester, Pa. The vessel is scheduled for delivery early in August 1938. The "J. W. Van Dyke," a tanker of the same tonnage and welded construction launched from the Sun Shipyards in November, is scheduled for delivery to The Atlantic Refining Company next month. The two tankers are the world's largest welded ships now under contract.

Conference on Welding Design and Practice*

Armour Institute of Technology

Three Weekly Meetings on Tuesday, Thursday and Friday at 7:30 P.M. During December 1937 and January 1938

Purpose

The Armour Institute of Technology has arranged a series of eighteen evening lectures on welding practice and design to be given during the first three weeks of December 1937 and the corresponding period of January 1938. These lectures are for the purpose of aiding engineers and welding technicians to obtain a general and yet scientific knowledge of the field of commercial welding. To this end the subject of design will be emphasized in many of the subjects listed.

Registration and Tuition

The registration fee is $35.00 for the course. Pre-registration may be made by mail. Letters should be addressed to the Registrar, Armour Institute of Technology. Personal registration will also be permitted at any time at the Registrar's Office, but no one will be permitted to attend any lecture until registration has been completed.

PROGRAM

All Lectures start at 7:30 P.M. at the Armour Institute of Technology.

Tuesday, November 30, 1937

Metallurgy and Heat Treatment of Welds by Dr. W. A. Pearl, Director of Engineering Shops, Armour Institute of Technology.

Thursday, December 2, 1937

Metallurgy and Heat Treatment of Welds by Dr. W. A. Pearl, Director of Engineering Shops, Armour Institute of Technology.

Friday, December 3, 1937

Heavy Pressure Vessels by L. J. Larson, Director of Welding Research, A. O. Smith Corporation.

Wednesday, December 8, 1937

Tank Welding Research and Design by H. C. Boardman, Research Engineer, Chicago Bridge & Iron Co.

Thursday, December 9, 1937

Pressure Tanks and Code Requirements by H. C. Boardman, Research Engineer, Chicago Bridge & Iron Co.

Friday, December 10, 1937

Highlights of Welding Design by C. S. Moody, Metallurgical Engineer, Northwest Engineering Co.

Tuesday, December 14, 1937

Jigs and Fixtures by James Shiffli, Product Engineer, American Steel Foundries.

Thursday, December 16, 1937

Design of Tall Steel Stacks for Welding by J. C. Sanderson, Structural Engineer, Sargent and Lundy.

Friday, December 17, 1937

Structural Welding Design by V. O. McClurg, Chief Structural Engineer, Holabird and Root, Architects.

Tuesday, January 4, 1938

Welding of Heavy Machinery by Westinghouse Manufacturing Co.

Thursday, January 6, 1938

Welding of Heavy Machinery by Westinghouse Manufacturing Co.

Friday, January 7, 1938

Research on Pipe Welding by E. R. Seablom, Research Welding Engineer, Crane Company.

Tuesday, January 11, 1938

Code Studies for Pipe Welding by E. R. Seablom, Research Welding Engineer, Crane Company.

Thursday, January 13, 1938

Railway Track Welding Research by G. M. Magee, Ass't Director, Research Division, Ass'n of American Railroads.

Friday, January 14, 1938

Construction and Maintenance of Modern Railway Equipment by G. M. Magee, Ass't Director, Research Division, Ass'n of American Railroads.

Tuesday, January 18, 1938

Maintenance of Railway Bridges by G. M. Magee, Ass't Director, Research Division, Ass'n of American Railroads.

Thursday, January 20, 1938

Building Design for Welding by A. M. Candy, Consulting Engineer, The Hollup Corporation.

Friday, January 21, 1938

Welding Practice and Design by A. M. Candy, Consulting Engineer, The Hollup Corporation.

* Sponsored by the Hollup Corporation.

Thirteenth Annual Conference on Welding Held at Purdue University

December 9–10, 1937

PROGRAM

Thursday, December 9th

Afternoon—1:30 P.M.

The Physico-Chemical Basis of Welding Electrode Coatings by J. C. Joublanc, Chief Metallurgist, Harnischfeger Corporation, Milwaukee, Wisconsin.

X-ray Technique for Inspecting Welds by F. W. Paine, Radiologist, Claud S. Gordon Co., Chicago, Illinois.

Flame Hardening by Russell Pursel, National Cylinder Gas Company, Chicago, Illinois.

Evening—7:30 P.M.

Design and Fabrication of Welded Parts from Rolled Steel by J. D. Gordon, General Manager, Fabricating Division, The Taylor-Winfield Corporation, Detroit, Michigan.

Friday, December 10th

Forenoon—9:00 A.M.

Modern Machine Cutting by R. F. Helmkamp, Applied Engineering Department, Air Reduction Sales Company, New York, N. Y.

Student Course for Welders by L. A. Wilkin, Development Engineer, Graver Tank & Mfg. Co., Inc., East Chicago, Indiana.

Low Alloy Steels by J. C. Hodge, Chief Metallurgist, The Babcock and Wilcox Co., Barberton, Ohio.

Afternoon—1:30 P.M.

Latest Welding and Fabricating Practice by W. R. Bernardi, Manager, Welding Section, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania.

Joining Copper Bus-bars with Brazing Alloys by R. A. Goeller, Vice-President, Hatzel & Buehler, Inc., New York, N. Y.

General Maintenance by W. B. Browning, Service Engineer, The Linde Air Products Company, Chicago, Illinois.

Special Demonstrations

A partial list of demonstrations scheduled during the meetings includes

Cutting Cast Iron
Bronze Welding with Electric Arc and Gas
Applying Hard Surface Metals
Atomic Hydrogen Welding
Welding Aluminum
Welding Cast Iron
Resistance Welding
Cutting with Gas
Metal Spraying
Fusion Welding Brass and Bronze
Tensile Test of Welds

Build New Gas Holder at Ford Rouge Plant

Plans for the construction of a new 2,500,000-cubic foot gas holder, the largest of its kind in U. S. Industry, were announced recently at the offices of the Ford Motor Company in Dearborn, Mich.

The new holder along with the company's new 10,000,000-cubic foot holder on which construction was begun some time ago will store blast furnace gas. Completion of the two holders will round out an extensive revision of the Ford Rouge plant's gas handling system designed to keep pace with the increased fuel needs of the increased production program.

The 2,500,000-cubic foot container will stand near the south boundary of the Rouge plant, along Dix Road, at the south end of two new coke oven batteries just completed. It will have a diameter of 128 feet and rise 225 feet into the air, as tall as an 18-story building. The holder will be of all-welded construction, of the waterless, center-column type.

Blast furnace gas production at the Rouge plant is variable. The new holder will store a supply of this gas to act as a sort of balance wheel for the Rouge blast furnace gas system. When blast furnace gas sources are temporarily unproductive, the supply in the holder will be used until coke oven gas can be diverted into the mains, thus insuring a steady flow of suitable fuel gas at all times.

The larger 10,000,000-cubic foot holder will be used to store coke-oven gas produced over the weekends, when the plant is not in full production. Gas will be taken from it as needed during the work week, 1,000,000 to 2,000,000 cubic feet each day. Thus, the holder will be filled each weekend and drained during the subsequent five working days.

The larger gas holder is 220 feet in diameter and 344 feet high—equal in height to a 34-story building.

The construction involves the use of welded rather than riveted plates, an innovation, and will require 3000 tons of structural steel plates and shapes, 25 tons of weld rod and 200 tons of miscellaneous equipment. Its reinforced concrete foundation will measure 1360 cubic yards, supported on 260 piles about 100 feet long, driven to bed rock. About one year will be required for completion of the project.

Oxyacetylene Process Depicted in New Educational Motion Picture Film

"Modern Metalworking with the Oxyacetylene Flame," a new two-reel silent motion-picture film that depicts the construction and operation of the oxyacetylene torch and the oxyacetylene process for joining and severing metals, is the latest addition to the film library of the Bureau of Mines, Department of the Interior.

Reel 1 illustrates how acetylene, the fuel gas for the oxyacetylene flame, is produced by the chemical action of water and calcium carbide and how oxygen, the gas that supports the combustion of acetylene, is utilized in producing the oxyacetylene flame of approximately 6300° F. By means of animated drawings and photography, every phase of the construction and operation of the "blowpipe," including pressure gages and adjusting screws, is shown graphically as well as the utilization of the oxyacetylene flame.

Reel 2 illustrates the use of the oxyacetylene process in cutting and welding metals, repairing damaged metal appliances, bronze-welding joints, welding pipe lines, and in the construction of all-metal automobile bodies. Scenes showing the use of oxyacetylene cutting machines in shop and foundry practice and the flexibility, economy and dependability of the oxyacetylene process conclude the story of this universal tool of all industry.

Copies of this film in 16-mm. and 35-mm. size may be had for exhibition by schools, churches, colleges, civic and business organizations and others interested. Applications for the film should be addressed to the Bureau of Mines Experiment Station, 4800 Forbes Street, Pittsburgh, Pa. No charge is made for the use of the film, although the exhibitor is asked to pay the transportation charges.

Copper Condenser Tubes

The A. S. T. M. has recently issued Tentative Specifications for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock (B111—37T) which I believe are of interest to your Society.

One reason for publishing any proposed standard as tentative is to give industry and all others concerned an opportunity to comment and to submit criticisms for the purpose of insuring, when finally adopted, a standard which would be entirely adequate and satisfactory. The A. S. T. M. is particularly desirous of securing the comments of the AMERICAN WELDING SOCIETY in respect to these specifications, a copy of which is enclosed. Copy will be furnished upon request to the American Society for Testing Materials, 260 South Broad St., Philadelphia.

Chicago Adopts Welding Code

The Chicago City Council on November 3rd passed a new ordinance relating to buildings and zoning. Under a section, headed "Steel and Metal Construction," welded fabrication is permitted, providing the welding is done in accordance with the AMERICAN WELDING SOCIETY Building Code, 1934 Edition. The new ordinance also specifies that welding materials shall also meet the A. W. S. 1934 Code. Allowable working stresses, tension, compression, bending and shear are specified for all types of structural connections, including welding.

Under another paragraph heading entitled "Construction Provisions," the new Chicago Building Ordinance specifies the manner of carrying out tests of structural welding. Provisions are made for a series of tests which must be certified to by the architect or engineer responsible for the design and then submitted to the Commissioner of Buildings.

This is the first code which permits higher unit design stresses for shielded arc welding and these stresses are in accordance with the new specifications recommended by the AMERICAN WELDING SOCIETY to be issued shortly.

Acetylene Congress

At this meeting in October 1937, the Permanent International Committee of Acetylene and Gas Welding decided to hold its Thirteenth International Acetylene Congress in Germany during the latter part of June 1939. The Committee is preparing a vocabulary of welding terms in French, German, English, Spanish, Dutch, Japanese and Portuguese.

Wooden Weld

Mr. Wm. Spraragen
Technical Secretary
AMERICAN WELDING SOCIETY
33 West 39th Street
New York, N. Y.

Dear Sir:

It has come to my attention that at a recent gathering of your august Society that one Dr. S. I. McPherson delivered a lecture in which he claimed to be the sole inventor of a process that could be used to weld wood. We do not wish to discredit the honorable Doctor but we are forced to accuse him of plagiarism as the use of arc welding in the Lumber Industry did not originate in his Laboratories in San Diego but in the Research Laboratory of the Wildwood Electrode Manufacturing Co. His claims that the basic secret of the welding of wood lies in the "Gripper Molecules" is far from true. The use of ionized sawdust coating made by our company in preparing our wooden electrodes is the only means of obtaining satisfactory welds in wood, and these patent covered coatings have been in existence for many years. We are of the opinion that Dr. McPherson's claims are not original but are based on work done by the Wooden Research Board which has been published in such magazines as *The Timberman and Industry* and *Welding* by the writer.

The statement by Mr. Llewellyn that "only Mac can weld a tree" should be retracted as the Wildwood Electrode Manufacturing Co. in their patent declaration in 1923 show a wooden welder rejuvenating and salvaging a famous historical tree by welding up a decayed spot and covering the spot with a layer of bark. Mr. Llewellyn is thoroughly familiar with the work of the Wooden Research Board and we are surprised that this man of steel should be taken in by such a faker as this so-called Doctor whom we are of the opinion is as false as his whiskers.

Where it is desired to reclaim knotted and splintered logs, join planks together, build up boards or to produce veneers of rare and costly woods, the Wildwood Elec-

trode Manufacturing Co. excells all others, in fact, we challenge Dr. McPherson to produce any of the results set forth in his talk without the use of our electrodes or generator (also set forth in our early patent specifications).

The Legal Department of our Company has been consulted and immediate steps will be taken to prosecute the Doctor on the grounds of infringement of patents of long standing.

Very truly,
(Signed) Douglas Fir
Managing Director,
Wooden Research Board

New Stevens Dormitory Opened

Jacobus Hall, the newly-completed dormitory presented to Stevens Tech. by William Slocum Barstow in honor of Dr. David S. Jacobus, was formally opened recently with a tea at which Barstow, Dr. Jacobus, President Harvey N. Davis and Mrs. Davis, members of the faculty and some of its trustees, and the students living in the new building, will be present. A special feature will be the unveiling of a tablet describing the building as Barstow's gift in honor of his friend.

The dormitory is the first of the new group of buildings on the campus.

Barstow and Dr. Jacobus are members of the board of trustees of the college and the latter is an alumnus. He was graduated in 1884 and was a member of the faculty from that time until 1906. He is now with Babcock & Wilcox. Barstow, whose home is in Long Island, is one of the Edison Pioneers and was for three years president of that association. He was largely responsible for the erection of Edison Tower at Menlo Park.

Steel Joist

A very attractive pamphlet has been issued by the Bethlehem Steel Company, Bethlehem, Pa., on the Bethlehem open web steel joists and their use in housing construction.

Flame Hardening

An attractive folder on "Flame Hardening" has been issued by the National Cylinder Gas Company of Chicago.

Book

Methods of Testing and Mechanical Properties of Plain-Carbon and Alloy Steels, being Section 1 of Part C of the books on IRON of Gmelins Handbuch der anorganischen Chemie, edited by Dr. E. Pietsch. Published by *Verlag Chemie*, Berlin W 35, Germany, 1937.

This book is the first section of Part C of System 59 of the famous Gmelins Handbuch. The first section has been prepared by Dr. E. Franke and deals with methods of Hardness Testing. It contains 162 pages, 105 figures and an index. The price is 25 RM (German Marks) but a reduction of 25% is allowed to purchasers in the U. S. A. The book is divided into three parts: (1) Methods of Hardness Testing (2) Hardness of Pure Iron and Plain Carbon Steels and (3) Hardness of Alloy Steels and Alloys of Iron.

Section 2 on Notch Impact Testing will soon appear.

Harold N. Ewertz

Harold N. Ewertz has joined the sales staff of Arcos Corporation as of January 1st. Mr. Ewertz is a graduate of the Massachusetts Institute of Technology. Prior to his connection with Arcos, he was in charge of all sales of welding equipment and supplies of the Austin-Hastings Co., Inc., Boston, Mass.

Lincoln Gold Medal Continued

At the Board of Directors' meeting held in Atlantic City it was announced that the Lincoln Electric Company would continue the Lincoln Gold Medal to be awarded annually for best paper of year presented before Section or National Meeting and published in THE WELDING JOURNAL.

Award of this Medal will be made by the Board of Awards which Board is also in charge of the award of the Samuel Wylie Miller Memorial Medal.

The Society is indeed fortunate to be able to offer annually these two outstanding medals.

New Partnership Formed

Mr. Gilbert D. Fish and Mr. Elwyn E. Seelye have formed a partnership to practice consulting engineering in the welding field.

This will include designs, inspections, estimating and details. The office of the new firm will be at 101 Park Avenue, New York City.

I. A. A. Convention

The 38th Annual Convention of The International Acetylene Association, held in Birmingham, Alabama, November 10th, 11th and 12th was one of the outstanding meetings in the history of the Association.

From the Opening Luncheon on Wednesday, at which nearly six hundred were served, to the final Technical Session on Friday afternoon, exceptional interest was shown in every phase of the program. The meeting was an inspiration to all who attended or who contributed in any way in its preparation.

A highlight of the Opening Luncheon was the presentation of the Morehead Medal to H. S. Smith, New York, "for his vision, inspirational guidance and aggressive cooperation in the advancement of the acetylene industry." Since Mr. Smith has also recently been announced as the recipient of the Samuel Wylie Miller Medal awarded by the AMERICAN WELDING SOCIETY, he thus becomes the first man ever to receive the two outstanding awards of the welding industry.

The Technical Sessions held on Wednesday, Thursday and Friday afternoons were each attended by three- to four-hundred members and guests of the Association. A feature of the first session on "Speeding Manufacture and Construction with Oxy-Acetylene Welding" was a number of papers on pipe welding which held much interest both from the technical and supervisory viewpoints. The second session on "How and Why to Use Oxy-Acetylene Cutting" also was received enthusiastically because of the many new developments in machine cutting during the past year. The final session on Friday afternoon on "Maintenance and Operation Uses of the Oxy-Acetylene Process" was featured by two papers on flame hardening and also proved of unusual interest.

The Round Table Discussions were again one of the most popular features of the program. The Engineering Session on Wednesday evening and the Operating Session on Thursday evening were attended by more than 1000 persons. The informal atmosphere which prevailed proved the value of this type of meeting for the frank discussion of pertinent phases of the oxyacetylene process.

The outstanding success of the 38th Annual Convention emphasizes the importance of the many new developments in the oxyacetylene process during the past year.

Arc Welding Catalog

The Hobart Brothers have just put out a very attractive new catalog on the new Hobart Simplified Arc Welders. Copies of this catalog will be sent on request by the Hobart Bros., Hobart Square, Troy, Ohio.

"What Is Single Current Control?"

A new book written with the sole purpose of answering this question and showing how single current control is used in the Hansen Smootharc Welding Generators has recently been written by Mr. F. J. Hirner of the Welder Division of the Harnischfeger Corporation of Milwaukee. Copies of this folder may be obtained by writing the Harnischfeger Corporation, 4400 W. National Avenue, Milwaukee, Wisconsin.

Consolidated Edison Welds Steam Lines

One of the largest welding jobs of its kind, the boilers and high pressure steam lines of the new 1200–1400 lb., 900° F. topping turbine for the Waterside Station of the Consolidated Edison Company of New York, Inc., are welded. The job is an exacting one and requires that the pipe area on each side of the joint be preheated before a weld is started and annealed when completed. Each weld must undergo an X-ray examination.

The enormous steam pressures and high temperatures that these lines will carry when finished makes it necessary to give the welding operators special instructions and tests before being qualified to work on the pipe joints. The main steam pipe is carbon molybdenum for which a special welding rod is used.

SECTION ACTIVITIES

ATLANTA, GA.

The following Officers have been elected by the Atlanta Section:

Chairman—M. C. Snead.

Vice-Chairman—A. D. Snipes.

Secretary—R. G. Wilson.

Treasurer—A. M. McCoy.

Representative on Board—D. B. Hunt.

Executive Committee for 1 year—W. R. Wilburn, E. H. Anchors.

Executive Committee for 2 years—R. J. Teeple, O. M. Harrelson.

This Section so far has had two very interesting meetings. The November meeting held on the 9th was at the Henry Grady Hotel.

The December meeting held on the 16th had an attendance of thirty-six. The meeting started with a motion picture on the subject "Progress of Welding," which was presented by R. G. Wilson. Mr. R. W. Sandelin, Metallurgist of the Atlantic Steel Company was the speaker of the evening. His subject was "The Significance and Importance of Simple Steel Analyses." Mr. Sandelin used lantern slides to illustrate his talk.

BIRMINGHAM

The Birmingham Section held their December meeting, on the 14th in the Auditorium of the Alabama Power Building. Mr. T. W. Allen of the Taylor-Winfield Corp., presented stills and motion pictures covering the redesign of cast bases to welded all-steel bases. The meeting was attended by 155 and the program was enthusiastically received.

It is planned to hold the January meeting on the 18th at which time Mr. Harry Boardman of the Chicago Bridge & Iron Company will present another phase of plate fabrication with welding.

BOSTON

At its meeting on Dec. 27, 1937, the Executive Committee of the Boston Section appointed P. J. Horgan to complete the unexpired term of H. N. Ewertz as Director.

CHATTANOOGA

The following officers have been elected by the Chattanooga Section:

Chairman—E. C. Chapman, Combustion Eng. Co.

Vice-Chairman—C. E. Kimball, Chattanooga Welding & Machine Co.

Secretary—C. T. Raymo, Chattanooga Boiler & Tank Co.

Treasurer—Jay D. Williams, Compressed Industrial Gases.

Membership Chairman—Robert Daniels, The Lincoln Electric Co.

Program Chairman—M. L. Holt, Chattanooga Welding Machine Co.

CHICAGO

Dr. G. V. Slottman of the Applied Engineering Department, Air Reduction Sales Co., prepared a paper on the subject of "Flame Hardening," but owing to his last minute inability to be present his paper was read by M. M. Weist of the same company.

Dr. Slottman's paper was illustrated with numerous lantern slides and a motion picture film in color. This was the first public showing of the new 16 mm. film depicting the application and shop technique of the flame hardening process.

Pullman-Standard Car Manufacturing Co. presented two motion picture films, one on welded freight car fabrication and impact testing of freight cars, the other film on shop welding details of passenger car fabrication. The latter picture was accompanied with sound reproduction direct from the film.

Mr. A. M. Unger, Welding Engineer of Pullman-Standard was kept busy answering questions following the presentation of the films. Most of the questions referred to technical details of spot welding as applied in the Pullman shops.

Dinner in the Skytop Room with an attendance of 48 preceded the meeting. The technical meeting had an attendance of 121.

CINCINNATI

The Cincinnati Section had a very interesting meeting on December 8th at which Mr. A. E. Gibson discussed the design and welding of low-alloy steel structures. Considering the abnormally inclement weather for this locality, the meeting was well attended and resulted in an interesting and lively discussion.

CLEVELAND

Mr. Robert M. Wallace of The Griscom-Russell Company, addressed the Cleveland Section on December 8th, on the subject "Welding in the Heat Exchanger Industry" with special reference to the use of alloy steels. Mr. Wallace delivered a very interesting and enlightening address and all who attended were well repaid.

Mr. A. L. Pfeil of The Universal Power Corp., was named Membership Chairman.

DETROIT

About 400 attended the joint meeting of the Detroit Section and the Society of Automotive Engineers at the Annual Meeting of the latter Society at Flint on December 8th. Two papers were presented, "The Fundamentals of Welding," by Dr. Comfort A. Adams and "Recent Developments in Resistance Welding" by Dr. F. R. Hensel of the P. R. Mallory Company. Much interest was shown in the papers and the discussion which followed. The very fine cooperation displayed by the Society of Automotive Engineers assured the success of the meeting.

KANSAS CITY

Mr. G. Raymond, Chief Engineer, Black Sivalls & Bryson, was the speaker of the December 20th meeting of the Kansas City Section. His address was on "A Revolution in Joints," which was a description of changes in Pressure Vessel Construction. An informal discussion followed Mr. Raymond's talk.

The next meeting will be held on January 17th. Mr. F. C. Fantz, Vice-President, Midwest Piping & Supply Co., Inc., will speak on "The Use of Welding in Industrial Power Plant Piping."

LOS ANGELES

The regular meeting of the Los Angeles Section was held on October 21st at the Central Manufacturing District Club with 44 members and guests present for the dinner and approximately 30 members and guests at the meeting. The first paper "Rackets of Today," was presented by Mr. Robert J. Bauer, General Manager of the Better Business Bureau of Los Angeles, Ltd. Mr. Bauer presented a very interesting discourse on fake promotions and other means to swindle the general public. He was followed by a very interesting sound film, "Finny Fighters" presented by the Union Oil Company of California.

The November meeting was held on the 18th at the Westgate Masonic Temple, in connection with the school being held by The Lincoln Electric Company. Wayne Howard, the Chairman, made a complete report to the Section on his trip to the Convention at Atlantic City, after which Mr. E. W. P. Smith, E.E., gave an interesting talk on "The Study of Stress Distribution in Welds," supplementing his lecture with some very interesting slides, using rubber models of various joints and connections and also an interesting study of stress distribution by means of the polariscope.

The next regular meeting was held on December 16th, on the 9th floor of the Chamber of Commerce Building. Approximately 85 members and guests were present. Wayne Howard explained to the members the new Welding Handbook.

Mr. Clayton M. Allen of the Department of Water and Power, City of Los Angeles, who arranged the program for this meeting, introduced the various men of the Department of Water and Power attending the meeting. The Male Quartette of the Department entertained the members with several selections, after which Mr. James E. Hood, Superintendent of Electrical Maintenance and Repair, General Plant Division, gave an interesting talk on the work and problems of his department in the maintenance, repair, and fabrication of large transformers and generators in use there, and various other interesting methods and applications in his department.

Mr. Hood was followed by another interesting talk by Mr. Martin Fleming, Machine Shop Foreman of the General Plant Division, describing the construc-

tion of the transformers and of transformer cars capable of carrying varying loads of twenty-five, fifty, one hundred and two hundred tons each.

MILWAUKEE

Mr. H. F. Falk, Vice-Chairman, having resigned, the Executive Committee voted to appoint Mr. R. E. Boeck in his place to act as Vice-Chairman until the Spring election. Mr. Boeck is welding superintendent of the Worden-Allen Company of Milwaukee and has been very active in the affairs of the AMERICAN WELDING SOCIETY.

NEW YORK

The regular monthly meeting of the New York Section was held on December 14th in the Engineering Societies Building. Mr. J. L. Wilson, of the American Bureau of Shipping was the Presiding Officer. Mr. Robert West of the Manitowoc Ship Building Corp., and Mr. Thomas M. Jackson of the Sun Shipbuilding & Drydock Co., addressed the meeting on "Automatic Welding in Ship Construction." Mr. West discussed the carbon-arc process and Mr. Jackson the Unionmelt welding process. Discussion by leaders of the industry and well-known naval architects followed.

The January meeting will be a joint meeting with the Machine Shop Practice Division of the American Society of Mechanical Engineers on Thursday, January 13, 1938 at 8:00 P.M., Room 501, Engineering Societies Building. Mr. H. E. Davies of the Pollak Manufacturing Company will address the meeting on "Jigs and Fixtures for Welding;" Mr. A. Kidd of the M. W. Kellogg Company, will speak on "Construction and Transportation of a Huge Welded Petroleum-Refinery Tank," discussing shop fabrication, and Mr. Richard Aldrick of the same company will describe the transportation by flotation of this huge tank to Whiting, Ind., by way of the Hudson River and the Great Lakes.

NORTHWEST

Mr. Harry J. Kicherer, Chairman of the Northwest Section, has joined the manufacturing staff of the Tractor Works, International Harvester Company, Chicago. Mr. Kicherer has been long recognized as one of the active leaders in the field of welding. Through his efforts as Chairman of the Membership Committee, The Northwest Section was organized and today is one of the most active units. The members on the night of October 15th gave Mr. Kicherer a rousing send-off to his new work. Mr. Alexis Caswell, Secretary-Treasurer of the Section, spoke highly of Mr. Kicherer's work with the organizing and program of the Section's activities.

C. E. Plummer, Technical Director, Chemical & Metallurgical Engineering, Robert W. Hunt Company, Engineers, presented a most interesting discussion on the topic of "Testing," illustrated by lantern slides, at the December 6th meeting. Mr. Plummer described fully some of the methods of determining the imperfections in welding practice and how many of them could be avoided by the use of proper methods and application. After the meeting the official motion pictures of the 1937 Minnesota football team in action were shown.

The program of meetings for the 1937–38 season, arranged by R. H. Newton, District Manager of The Lincoln Electric Company, Chairman of the Program Committee, offers to members a most interesting and valuable series of discussions on important subjects by men who are recognized as authorities in their respective fields.

The Membership Committee, headed by J. E. Williams, District Manager of The Linde Air Products Company, is organizing a comprehensive plan to increase the membership of the Society.

The Lincoln Electric Company has announced an educational course on certain phases of "Welding" to be conducted by E. W. P. Smith, Consulting Engineer, of the Company, at Dunwoody Industrial Institute, Minneapolis, during the evening of January 19th, 20th and 21st. The course is designed especially for engineers and supervisors of welding, and will include demonstrations after the lectures. Enrollment will be limited to 200, and a charge of $3.00 will be made for the complete course, which will be similar to those given in other cities throughout the country.

OKLAHOMA CITY

The December meeting of the Oklahoma City Section of the AMERICAN WELDING SOCIETY was held Tuesday December 7th in the East Room of the Biltmore, Hotel, this being the first of a series of dinner meetings to be held throughout the year.

Forty members and guests enjoyed the dinner and the hour of sociability which accompanied it.

The interest in the work of the Oklahoma City Section was evident by the fact that several of our guests were from out of the city some of these guests travelling quite a distance in order to be present.

The entire meeting was very informal and after the dinner that portion of the meeting which might be termed as the regular business meeting was opened by the presentation of a motion picture entitled "The Prosperity Process." This picture was presented through the courtesy of the Linde Air Products Company and was very interesting in that it showed the practicability and adaptability of Oxy-acetylene cutting, welding and hard surfacing.

The address of the evening was given by Mr. R. W. VanKirk of Dallas, Texas. Mr. VanKirk is a welding specialist of recognized ability with the General Electric Company.

The subject of the address was "The Practical Value of D.C. Welding Generator Characteristics."

Mr. VanKirk made his remarks very impressive by building a typical welding generator set on the black board describing the construction and purpose of the principal parts of such a set as he added them to the picture and summarized his remarks when the drawing was completed by stating the advantages and disadvantages of various characteristics of the average type of welding machine.

The customary open forum discussion followed the address and questions were asked—the answers to which were of considerable value not only to the one asking the question but to all those present.

PHILADELPHIA

Mr J. F. Lincoln, of The Lincoln Electric Company, will talk on Electric Welding Progress, at the January 17th meeting of the Philadelphia Section which will be held in the Engineers' Club, Philadelphia, at 8 P.M.

PITTSBURGH

The next regular meeting of the Pittsburgh Section will be held in the East Room of the Roosevelt Hotel, this city, January 19, 1938, at which time Mr. C. H. Jennings, Research Engineer of the Westinghouse Electric & Manufacturing Co., will give a talk on "European Welding Practice."

Mr. Jennings has just returned from an extensive tour of the European countries and his talk will be looked forward to by many interested in what others are doing in the welding field.

Structural details for the Women's Wing of the University Hospital, Pittsburgh, Pa., have been completed and prices are now being taken on the erection and welding of same. This is the 1000 ton, 14-story welded building, reported a short while ago as the first large all-welded building in this city for which a permit has been granted. Fabrication of the steel has been let to the Bethlehem Steel Corporation. Erection is scheduled to start about Jan. 20, 1938.

SAN FRANCISCO

The regular monthly meeting of this Section was held on November 19th. Chairman N. F. Ward opened the meeting at 8 P.M. Proposal for a change in the By-Laws was discussed and acted upon at the meeting, and a proposal relative to change of dates as to the appointment of Nominating Committee, report of the Nominating Committee and the annual election, necessitated further changes in the By-Laws. H. W. Saunders, Chairman of the Membershp Committee, was then called upon for a report. Chairman N. F. Ward announced that the next meeting would be more or less of a social nature and would be held on December 17th. Chairman Ward reviewed the activities at the Convention of the Society in Atlantic City.

As announced at the November Meeting the December 17th meeting was a purely social event, at which a good time, a good show, singing, dancing, comedy, etc., and good drinks appropriate for the season, were enjoyed by all, at the Athens Athletic Club, Oakland.

ST. LOUIS

The December meeting was held on the 10th in the German House Auditorium. Mr. G. O. Hoglund of the Aluminum Ore Company delivered an address on "Welding of Aluminum and Its Alloys," which brought out up-to-date information concerning the welding of aluminum.

SOUTH TEXAS

The following Program Committee has been selected for the South Texas Section:

Gil V. Dye, Hollup Corp., Houston.

G. W. Woods, Hughes Tool Co., Houston.

M. P. Hare, 1001 Electric Building, Houston.

J. R. Donaldson, Chicago Bridge & Iron Works, Houston.

WASHINGTON

The third meeting of the Washington Section was held on December 7th in the Old Interior Building. The meeting was attended by 85. Mr. H. W. Pierce, Welding Engineer of the N. Y. Shipbuilding Corp., gave an interesting talk on "Welding Problems in Ship Construction."

The first Educational Meeting was held on November 23rd at the George Washington University. This first meeting was devoted to a discussion of the Chart of Welding Processes. About 45 were present. Opportunity was provided for those present to make suggestions as to what should be covered in the next lecture and also questions which they would like to have answered. The Dec. 14th Educational Meeting was devoted to a general discussion of Structural Steel Welding. About 25 were present. Mr. A. G. Bissell has been conducting these Educational meetings.

Sections in Process of Formation

LOUISVILLE

On November 16th the Engineers and Architects Club of Louisville held a joint meeting with the members of the AMERICAN WELDING SOCIETY. Mr. H. C. Boardman, Divisional Vice-President, gave an interesting and instructive talk on "Field Welding of Tanks, and the Qualification of the Welding Processes and Operators." An invitation was extended to all present to become members of the AMERICAN WELDING SOCIETY. Other educational meetings are being arranged by Dean Bridgeman of Louisville University.

MEMPHIS

On November 8th a preliminary meeting was held at which B. B. Drury of the Modern Engineering Company was selected as Chairman. This district has some hundred important users of welding and flame cutting and about a dozen important welding shops, representatives of which are prospective members of a Section in this vicinity. It is planned to establish this Section early in 1938.

NEW ORLEANS

An Organization Meeting of the New Orleans Section was held at the St. Charles Hotel on November 15th. About 35 people were present. Mr. A. E. Gibson, Past-President of the Society and President of the Wellman Engineering Company, presented an address on "Welding of Mechanical Equipment." After Mr. Gibson's address, Mr. Warner S. Hays, Managing Director, outlined the work of the Society and it was unanimously voted to organize a Section. The following temporary officers were selected:

Temporary Chairman—O. B. McLaughlin, Freeport Sulphur Co.

Temporary Secretary-Treas.—J. H. Bull, Lester Alexander Co.

Temporary Vice-Chairman—A. H. Guillot, N.O. Public Service, Inc.

ROCHESTER

A preliminary organization meeting was held on December 16th at Todd Union Building of University of Rochester. The Managing Director of the Society described the activities of the Society. Mr. J. S. Gaylord was elected Temporary Chairman and he appointed a Nominating Committee, By-Laws and Membership Committees. 26 representatives pledged that they would become members of the Society and assist in the formation of the Rochester Section. A formal organization meeting is scheduled for January 6th. This Section has been assured of the support of the University and many of the old timers connected with the AMERICAN WELDING SOCIETY. Cooperation with chapters of other national engineering societies is contemplated.

SAN JOAQUIN VALLEY

Meeting held on November 18th in the Spanish Ball Room, El Tejon Hotel, Bakersfield, Calif. Mr. Harold Etter, Manager of the Los Angeles office of the Air Reduction Sales Company, presented an interesting account of the Annual Meeting of the Society held in Atlantic City. He indicated the aims of the Society and benefits to be derived from membership therein. Mr. F. W. Shrader, President, Shrader Electric Co. Inc., gave a brief and interesting talk on "Rising Popularity of Alternating Current Welding Machines.

A colored film "Hardfacing News," by the Stoody Company was next presented.

Mr. J. Emery, engineer, Air Reduction Sales Company, followed with a short talk on some of the interesting developments of "Flame Hardening."

The Union Oil Company of California presented the silent film version of the picture "Boulder Dam."

TOLEDO

The Toledo Section held an organization meeting Monday, December 13th, in the University of Toledo. Mr. A. E. Gibson, President, Wellman Engineering Company, presented an address on "Welded Fabrication and Design." Some 200 people were present. Mr. L. C. Monroe, Secretary of the Chicago Section, gave a review of the benefits to be derived from affiliation with the AMERICAN WELDING SOCIETY.

A second meeting was planned for January at which time it is hoped that the Section organization will be completed.

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-244. Welder desires position. Have just completed a course in the New York Trade School on Electric Welding and have been awarded a diploma. Would like position as Junior Welder or helper somewhere in the vicinity of New York.

A-245. Government qualified arc welder desires position. Three years' experience. Reference.

A-246. Welding Supervisor. Experienced in power plant welding, carbon, carbon-molybdenum piping, pressure to 1700 lb., qualifying Class 1 welders, resistance and induction stress relieving, arcronograph recording. Age 34. Member of United Association and AMERICAN WELDING SOCIETY. Will go anywhere.

A-247. Electric and Acetylene welder with six years' experience. Has own acetylene welding and cutting equipment. Among the companies worked for are the following: John Ring Company, Jones & Laughlin Steel Corp., United Shipyards, Inc.

A-248. Would like position as foreman of small welding shop. Have had 12 years' experience as a welder, electric and acetylene. Can furnish excellent references as to ability and technical knowledge of welding all types of alloy metals, also the testing and qualifying of welders.

A-249. Welding Supervisor and Inspector desires position. Have had 16 years' experience in all phases of welding. Experience includes construction field work, procedure control, layer-out, erector and iron worker. Understand blueprints. Can also draw workable sketches. Understand the design of simple beams, columns and their connections. Am acquainted with regulations and requirements of welding qualification of welders. Can organize and qualify welding crews.

A-250. Welder desires position. Have had a thorough course of instruction in welding.

POSITION VACANT

V-84. Experienced Salesmen. We are in need of several salesmen for different sections of the U. S. having experience in the sale and methods of application of the highest grades of hard facing metals. Product while new has already been adopted by numerous industries. Material made in several grades is extremely hard, has great wear characteristics, will withstand heavy impact.

CHAIRMEN AND SECRETARIES OF SECTIONS AND REGULAR MEETING DATES

To Members
AMERICAN WELDING SOCIETY

When in any city where sections of the Society are located—try to attend the meetings if held during your visit. This will widen your contacts in welding and enable you to interchange experience with others in similar lines of business. If no regular meeting date is given telephone the Secretary and he will gladly tell you.

ATLANTA, GA. — **1st Tues.**
CHAIRMAN—M. C. SNEAD, Link Belt Co., 1116 Murphy Avenue, S. W.
SECRETARY—R. S. WILSON, 139 Simpson St., N. W.

BIRMINGHAM — **3rd Fri.**
CHAIRMAN—E. E. MICHAELS, Chicago Bridge & Iron Co., P. O. Box 277
SECRETARY—J. E. DURSTINE, Lincoln Elec. Co., 505 No. 22nd St.

BOSTON — **3rd Fri.**
CHAIRMAN—P. J. HORGAN, General Electric Co., Lynn, Mass.
SECRETARY—P. N. RUGG, Boston Edison Co., 39 Boylston St.

CHATTANOOGA, TENN.
CHAIRMAN—E. C. CHAPMAN, Combustion Engineering Co., Hedges-Walsh-Weidner Div.
SECRETARY, CHESTER T. RAYMO, Chattanooga Boiler & Tank Company, 1030 East Main St., Chattanooga

CHICAGO — **3rd Fri.**
CHAIRMAN—TOM JONES, 8244 East End Ave.
SECRETARY—L. C. MONROE (Webster 7134), The Welding Engineer, 608 So. Dearborn Street.

CINCINNATI, OHIO
CHAIRMAN—W. W. PETRY, Cincinnati Milling Machine Co., Cincinnati
SECRETARY—J. K. ROSS, United Welding Company

CLEVELAND — **2nd Wed.**
CHAIRMAN—E. R. BENEDICT, Contract Welders, Inc., 2445 E. 79th Street
SECRETARY—E. T. SCOTT, Cleveland School of Welding, 2261 E. 14th St.

CONNECTICUT
CHAIRMAN—E. R. FISH, The Hartford Steam Boiler Insp. & Ins. Co., Hartford
SECRETARY—H. A. PENNINGTON, 196 Chapel Street, New Haven

DETROIT — **1st or 2nd Fri.**
CHAIRMAN—VAUGHAN REID, City Pattern Works, 1165 Harper Ave.
SECRETARY—H. P. DOUD, General Electric Company, 700 Antoinette St.

HAWAII — **4th Tues.**
CHAIRMAN—E. E. HEACOCK, Hawaiian Gas Products Ltd., P. O. Box 2454, Honolulu, T. H.
SECRETARY—R. L. MULLEN, Honolulu Iron Works Co., Honolulu, T. H.

INDIANAPOLIS,
CHAIRMAN—R. D. EAGLESFIELD, 357 S. La Salle St.
SECRETARY—I. L. WILLIAMS, P. R. Mallory & Co.

KANSAS CITY, Mo. — **3rd Mon.**
CHAIRMAN—C. E. WOODMAN, Kansas City Bridge Co., 215 Pershing Rd.
SECRETARY—ALBERT W. ROTH, 1531 Broadway

LOS ANGELES — **3rd Thurs.**
CHAIRMAN—WAYNE A. HOWARD, General Petroleum Corp., 2525 E. 37th St.
SECRETARY—J. C. GOWING, P. O. Box 186, Huntington Park, Calif.

MARYLAND — **3rd Fri. except April**
CHAIRMAN—DR. J. W. MILLER, Reid Avery Co., Ches. & Cleveland Aves., Dundalk, Md.
SECRETARY—C. N. HILBINGER, Lincoln Electric Company, Baltimore, Md.

MILWAUKEE — **2nd Wed.**
CHAIRMAN—K. L. HANSEN, Harnischfeger Corp.
SECRETARY—J. J. CHYLE, 2841 N. 51st

MONTANA — **1st Wed.**
CHAIRMAN—HENRY F. C. RUMFELT, 701 Musselshell, Fort Peck
SECRETARY—ALLEN W. BATES, Apt. 4503D, Fort Peck, Montana

NEW YORK
2nd Tues. except when Joint Meeting is held
CHAIRMAN—R. W. BOGGS, The Linde Air Products Co., 205 E. 42nd St.
SECRETARY—MILTON MALE, U. S. Steel Corp., 71 Broadway

NORTHWEST — **3rd Wed.**
CHAIRMAN—W. E. MURPHY, Northern States Power Co., Minneapolis
SECRETARY—ALEXIS CASWELL, Manufacturers Assoc. of Minn., 405 Marquette Ave., Minneapolis

NORTHERN N. Y. — **Last Thurs.**
CHAIRMAN—W. F. HESS, Rensselaer Polytechnic Inst., Troy, N. Y.
SECRETARY—G. A. ROSS, General Electric Co., Schenectady, N. Y.

WESTERN N. Y. — **Last Mon.**
CHAIRMAN—H. J. SCHLEIDER, Air Reduction Sales, 730 Grant St., Buffalo
SECRETARY—F. O. HOWARD, Am. Steel & Wire Co., 1403 Liberty Bank Bldg., Buffalo, N. Y.

OKLAHOMA CITY — **1st Tues.**
CHAIRMAN—O. T. BARNETT. Black, Sivalls & Bryson, Inc., Box No. 1377, Okla. City, Okla.
SECRETARY—K. B. BANKS, P. O. Box 1377, Okla. City, Okla.

PHILADELPHIA — **3rd Mon.**
CHAIRMAN—T. M. JACKSON, Sun Shipbuilding & D. D. Co., Chester, Pa.
SECRETARY—H. E. HOPKINS, Arcos Corp., 401 N. Broad St.

PITTSBURGH — **Middle Wed.**
CHAIRMAN—LEON C. BIBBER, Carnegie-Illinois Steel Corp., Carnegie Building.
SECRETARY—J. F. MINNOTTE, Minnotte Bros., 1201 House Bldg.

PORTLAND — **No dates set**
CHAIRMAN—G. C. DIERKING, Steel Tank & Pipe Co., P. O. Box 1899, Sta. F
SECRETARY—L. M. PICKETT, Steel Tank & Pipe Co., P. O. Box 1899, Sta. F

SAN FRANCISCO — **Last Fri.**
CHAIRMAN—N. F. WARD, University of Calif., Berkley, Calif.
SECRETARY, J. G. BOLLINGER, Air Reduction Sales, Park & Halleck Sts., Emeryville, Calif.

ST. LOUIS — **2nd Fri.**
CHAIRMAN—A. W. HARRIS, 2449 Milk Avenue, Alton, Ill.
SECRETARY—C. W. S. SAMMELMAN, 4359 Lindell Blvd., Engineers' Club

YOUNGSTOWN (Ohio) — **2nd Mon.**
CHAIRMAN—CHARLES WATSON, Youngstown Welding & Engr. Co.
SECRETARY—C. A. WILLS, Wm. B. Pollock Co., Youngstown, Ohio.

SOUTH TEXAS
CHAIRMAN—MARVIN COOK, Humble Oil & Refining Co., Houston
SECRETARY-TREAS.—MALCOLM V. REED, P. O. Box 3052, Houston

WASHINGTON, D. C. — **1st Tues.**
CHAIRMAN—A. G. BISSELL, Bureau of Construction and Repair, Navy Dept., Washington, D. C.
SECRETARY—C. A. LOOMIS, Bureau of Construction & Repair, Navy Dept., Washington, D. C.

SECTIONS BEING DEVELOPED

There is shown below Sections in process of organization and the name of the contact man in each locality. This contact man is either Chairman or Secretary of an active group interested in the formation and completion of Section Organization. Those members desiring to assist should communicate with these individuals.

CANTON, OHIO (Akron, Alliance, etc.)
ROBERT M. WALLACE, The Griscom-Russell Company, Massillon, Ohio

COLORADO
J. H. JOHNSON, Intermountain Belting & Packing Co., Denver, Col.

COLUMBUS, OHIO
PROF. O. D. RICKLY, Ohio State University

MIAMI VALLEY (Dayton, Troy, etc.)
E. STANSEL, Frigidaire Division, General Motors Corp., Dayton, Ohio

DALLAS-FORT WORTH, TEXAS
E. E. DILLMAN, Wyatt Metal & Boiler Works, Dallas, Texas

FORT WAYNE, INDIANA
JAMES MCCLURE, Wayne Welding Supply Co., 513 East Wayne St., Fort Wayne, Indiana

LOUISVILLE, KY.
A. HURTGEN, Henry Vogt Machine Company, 10th & Ormsby Streets

MEMPHIS, TENN.
B. B. DRURY, JR., Modern Engineering Company, 238 South Front St.

NEW ORLEANS, LA.
O. B. MCLAUGHLAN, Freeport Sulphur Co., Chairman
J. H. BULL, Lester Alexander Co., Secretary

OMAHA, NEBRASKA
L. O. SCHNEIDERWIND, Omaha Welding Company, 1501 Jackson Street

ROCHESTER, N. Y.
THOS. S. GAYLORD, Eastman Kodak Co.

SAN JOAQUIN VALLEY
H. S. NIX, Box 1364, Taft, Calif.

TOLEDO, OHIO
J. W. SHUGARS, The Lincoln Electric Company, 632 Spitzer Building

TULSA, OKLAHOMA
R. R. THOMPSON, Air Reduction Sales Company, Tulsa, Oklahoma

WICHITA, KANSAS
R. L. TOWNSEND, Phillips & Easton Supply Co.

THE ENGINEERING FOUNDATION
WELDING RESEARCH COMMITTEE

Sponsored by the American Welding Socieiy and American Institute of Electrical Engineers

Supplement to the Journal of the American Welding Society, January 1938

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Welding Research Activities

Elsewhere in this issue there is given a proposed program of research by the Industrial Research Division to study the Effect of Carbon and Manganese on the Weldability of Steel. This broad subject deserves careful consideration by all those identified with the Welding Industry. Comments, criticisms and helpful suggestions for cooperation are earnestly invited. These should be sent in promptly.

O. E. Hovey Appointed Engineering Foundation Director

Members of the AMERICAN WELDING SOCIETY and the Welding Research Committee will be highly pleased to learn that one of its own members, Dr. Otis E. Hovey, has been selected as the Director of Engineering Foundation.

Dr. Hovey is well known to members of the Society, having served for a number of years on its Board of Directors, its Executive Committee, Membership Classification Committee, Bridge Committee, Structural Steel Welding Research Committee, Meetings and Papers Committee and many others.

Dr. Hovey was born in East Hardwick, Vermont. He is a graduate of Dartmouth College where he obtained his Bachelor's Degree in 1885. This was followed by a Civil Engineers' Degree from the Thayer School in 1889. Dr. Hovey has exceptional experience in railroad engineering and in steel design. He has taught at Washington University in St Louis, and served for six years with the late George S. Morrison on bridge and other engineering design. Dr. Hovey served with the Union Bridge Company at Athens, Pa., from 1896 to 1900 and in 1900 he transferred to the newly organized American Bridge Company. He served for seven years as a designing engineer and then became Assistant Chief Engineer of the company, a position he held for twenty-four years. During this period Dr. Hovey's work was largely in bridge design, railroad and highways, and other types of structures. He became one of the world's greatest authorities on the subject of movable bridges. He wrote a two volume treatise on the subject which has become standard for such work. For three years from 1931 to 1934, he was Consulting Engineer of the American Bridge Company, and since that time has been in private practice as consulting engineer.

O. E. Hovey

In addition to being active in the work of the AMERICAN WELDING SOCIETY, Dr. Hovey has served the A. S. C. E. for 45 years in various capacities, including that of Treasurer of the Society for the past 17 years.

He has lectured at Dartmouth, Yale, Princeton and Brooklyn Polytechnic Institute. He received an Honorary Degree of *Doctor of Engineering from Dartmouth in 1927* and of *Doctor of Science from Clarkson College in 1933.*

Dr. Hovey, brings to the Engineering Foundation, and indirectly to the Welding Research Committee, a thorough knowledge of engineering and engineers He is keenly aware of the importance of fundamental and applied researches in all branches of engineering, and particularly in welding.

The Welding Research Committee is fortunate in having Dr. Hovey accept membership on its newly organized Fatigue Welding Research Committee.

Translations

Professor Eric Therkelsen of Montana State College has made available translations of the following German articles.

Progress in Metallic Arc Welding of Aluminum and Its Alloys. By Carl Auchter, published in *Zeit. Metallkunde*, **29** (9) 310–315, Sept. 1937. (New German covered electrodes for each type of aluminum alloy; mechanical properties; microstructure; very little is said about the composition of the electrodes and coatings.)

Research on Welded Aluminum Alloys. By Emil von Rajakovics, published in *Zeit. Metallkunde*, **29** (9) 315–318, Sept. 1937. (Mechanical properties of oxy-acetylene and atomic hydrogen welded aluminum alloys; effect of hammering; age hardening of welds; spraying of welds with metallic aluminum alloy to increase corrosion resistance.)

Discussion of Reviews

In the section on Oxyacetylene Welds with Restraint in the review of literature on Shrinkage Stresses in Welding (November Research Supplement) it was stated that the X-ray photographs indicated that the welds tested by Bühler and Lohmann were low-grade. In a recent letter Dr. Wilhelm Lohmann states that the welds made by correct procedures were of high quality, but many of the specimens he tested for shrinkage stresses had necessarily to be be made by incorrect procedures to determine their effect on shrinkage stresses. He found that it was difficult to avoid cracks in welds in high tensile steels (S_t52) if incorrect procedures were adopted, that porosity was unavoidable with bare electrodes, and that penetration was not so good with left-hand gas welding as with right-hand gas welding. Incorrect procedures led to low-grade welds from the X-ray standpoint.

In all of the tests cited by Mr. B. D. Landes in his discussion on Welding Wrought Iron (October Research Supplement, pages 71–72) fracture occurred in

(*Continued on page 19*)

EFFECT OF CARBON-MANGANESE

on the Weldability of Plain-Carbon Steels

TO THE WELDING INDUSTRY:

The Committee on Plain Carbon Steels of the Industrial Research Division has prepared a program of research on the subject of "The Effect of Carbon and Manganese on the Weldability of Steels."

A comprehensive survey of the literature was made under the auspices of the Literature Division and published in the September Research Supplement. This review indicated a lack of quantitative data on the above subject made under the same conditions of welding, and with the same types of steels.

This program will involve a considerable expenditure as it is desired to secure in advance all constructive comments, criticisms and suggestions possible. For this reason there is reproduced below the proposed program, and every one who has any interest in the subject is respectfully requested to communicate with the Welding Research Committee, 29 West 39th Street, New York, on or before February 15, 1938.

Attention is invited to the range of steels that it proposes to investigate. Naturally each range of steel adds to the cost of the program. It is especially desired to know what range of carbon and manganese various industries are interested in. Comments as to the interest of any unit of industry in any part of the program will be of great assistance in estimating its value.

In undertaking this work it is desired not to duplicate work already undertaken in any laboratory. Will those interested please furnish, for the information of the Committee, copies of research reports covering the subjects above, not already published and available? If some of these reports are to be considered confidential, it is requested that it be so indicated in transmittal.

Respectfully submitted,

G. F. JENKS
Colonel, Ord. Dept., U. S. A.
Chairman, Industrial Research Division

Effect of Carbon-Manganese on the Weldability of Plain-Carbon Steels

SCOPE

1. The study of the heat effects produced by fusion welding or gas cutting on the base metal adjacent to the weld as revealed by changes in hardness, toughness and tendency to cracking.
2. To determine the physical properties of the welded joint and the parent plate in steels of varying carbon and manganese content.

MATERIAL FOR TESTING

In order to perform the work of this research the following materials are desired:

Manufacture.—The steel shall be made by the electric furnace process, and all heats are to be poured from the same furnace. Unless otherwise specified for any particular testing, this material is to be normalized in accordance with the requirements defined by The American Society for Metals. (See table below.)

Chemical

Residual elements to be analyzed for information only.

Chemical analysis to be taken at the top corner of the plate in the direction of rolling. The sample shall be representative of the full cross section of the plate.

Carbon and Manganese

Carbon	Manganese				
0.10–0.13	0.30–0.40	0.60–0.75	0.90–1.10	1.20–1.40	1.50–1.70
0.20–0.24	0.30–0.40	0.60–0.75	0.90–1.10	1.20–1.40	1.50–1.70
0.30–0.35	0.30–0.40	0.60–0.75	0.90–1.10	1.20–1.40	1.50–1.70
0.40–0.45	0.30–0.40	0.60–0.75	0.90–1.10	1.20–1.40	1.50–1.70

Variation in chemical permitted	
Silicon (no other deoxidizer)	0.15 to 0.25%
Sulphur	0.025 to 0.04%
Phosphorus	0.040% Max.
Total other elements (with no single element being over 0.10%)	0.50% Max.

Dimensions of Plates

	Length		Width		Thickness
1 Plate	72 in.	×	36 in.	×	1/2 in.
1 Plate	72 in.	×	36 in.	×	1 in.
1 Plate	72 in.	×	36 in.	×	1 1/2 in.

In addition to the above plates, the following material is requested for testing:

Group VIII.

1 Plate 72 in. long × 36 in. wide × 1 in. thick to be made from 0.20 to 0.24% carbon with 0.60 to 0.75% manganese.

1 Plate 72 in. long × 36 in. wide × 1 in. thick to be made from 0.30 to 0.35% carbon with 0.90 to 1.10% manganese.

Direction of rolling to be stamped on each plate.

Each plate to be stamped with a proper number identifying the heat from which it was poured.

RESEARCH PROGRAM

In order to supply the information on the subject given in the SCOPE, the following program of research is suggested:

I. Hardness

Welding.—Single bead deposits are to be "welded" under reproducible conditions on the surface of a specimen from each steel using the 1/2 inch thick plate.

It is proposed that this bead be run at room temperature (70° F.) as follows:

Weld Speed In./Min.	Amps.	Volts	Electrode
6 in.	*	*	3/16 in.
18 in.	*	*	3/16 in.

(* To conform to best practice as recommended by the rod manufacturer for this diameter of rod.)

Electrode shall be heavily flux-coated conforming to the A. S. T. M. specification for welding.

The same grade of electrode shall be used throughout.

TEMPERATURE OF BASE METAL FOR WELDING

At a welding speed of 6 inches a minute, the following temperatures of the base metal shall be employed prior to welding:

−10° F.
70° F.
150° F.
300° F.

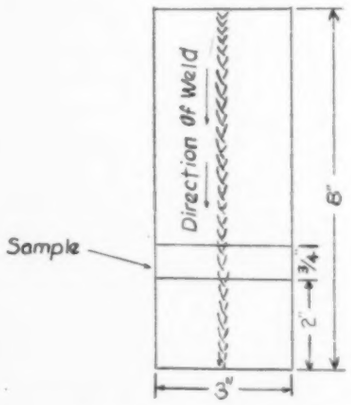


Fig. 1

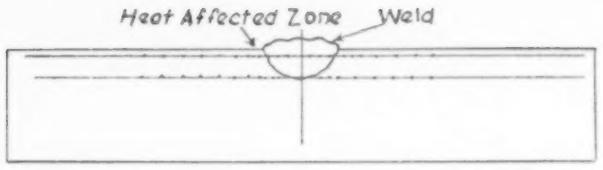


Fig. 2

For the −10° F. sample, the width of the plate specimen is to be greater than for the other experiments, and the cross section is to be selected as close as possible to the start of the weld. In order to obtain information on the characteristic distribution of heat during welding, thermocouples are to be used during the welding on one steel from the above list welded at 70° F.

The preheating temperatures of 150 and 300° F. are to be conducted only on those steels whose hardness, when welded at room temperature, is increased more than 60% over the original hardness of the unaffected plate.

Selection of Hardness Specimens.—The hardness specimen shall be taken from each plate with the bead deposited on the surface. The test sample is to be selected at a distance of not less than 2 inches from the crater, nor is it to be taken at a distance of less than 3 inches from the start of the "weld."

Stress Relieving.—In order to study the effect of stress relieving on the hardness and the microstructure of the affected metal adjacent to the weld, samples are to be taken from the welded test plate and subjected to the usual stress-relieving conditions. Stress relieve at 1175 to 1200° F., hold one hour and withdraw from the furnace at 500° F.

Hardness Measurements.—The hardness shall be measured by means of the Vickers Brinell machine on the cross section of the polished and etched specimen. The impressions shall be run in a line through the affected zone below the base of the weld. A second line is to be carried out across the weld below the surface of the plate, see Fig. 2.

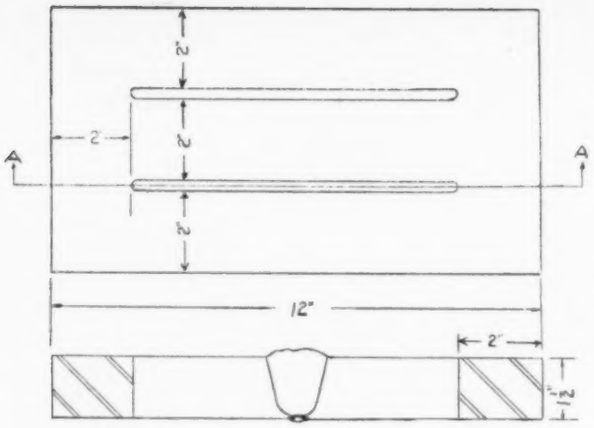
The impressions are to be 0.02 inch apart in the heat-affected zone and 0.05 inch apart in the unaffected plate and in the weld. The impressions are to be carried approximately 1 inch on each side of the deposit.

Microscopic Examination.—Photomicrographs are to be obtained showing the heat-affected zone in the metal adjacent to the weld.

II. Weld Quench Tests

Samples of each of the steels will be subjected to a series of heating and cooling operations to simulate the effect of the heat of welding on the base metal. The specially heat-treated samples should have the hardness and microstructure of the coarsest grains directly adjacent to the weld metal. The treatment of the samples will be regulated to match the hardness and structure adjacent to a single bead deposit made with 3/16 inch heavily coated electrodes, on 1/2-inch plates at room temperature, and at a speed of 6 inches per minute.

The size of the samples should be $0.202 \begin{smallmatrix}\text{plus } 0.005\\ \text{minus } 0.000\end{smallmatrix}$ x $0.399 \begin{smallmatrix}\text{plus } 0.005\\ \text{minus } 0.000\end{smallmatrix}$ x 2 inches. Three samples of each steel should be heat treated and tested. After the heat treatment, the specimens should be machined to the dimensions of a 1/2 inch wide Charpy bar (197 inches x 0.394 inch x 2 inches) with the keyhole notch. The bars should be tested in a Charpy machine to determine their notch toughness in foot pounds at room temperature.



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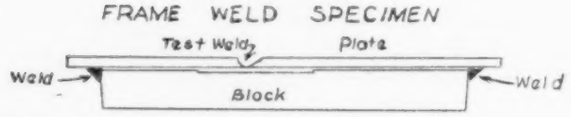

REVISED RIGID FRAME

Fig. 3

The above test is recommended along with the selection of tensile impact tests to be made on several steels under several conditions of welding. This is to show the trend and to aid in correlating the two impact tests.

III. Rigid Frame Weld Test (See Fig. 3)

This test is to be run on steels containing 1.20 and 1.50% manganese with 0.30 to 0.40% carbon in a plate thickness of $1^1/_2$ inches. If cracks are found, this test will be continued to include the other steels in the series of this thickness and the remaining thicknesses. Preheating treatments will then be supplied to study the effect of preheating prior to welding these plates as a means of preventing the formation of cracks in this type of weld.

It is desired to study the tendency to cracking by the use of magnaflux, radiograph and the microscope in the affected area, as well as tensile impact testing of the welded joint.

Microscopic Examination.—Samples taken from this joint are to be examined by the use of the microscope and photomicrographs of appropriate magnification obtained. Hardness surveys are to be made across the weld through the affected zone and through the unaffected plate metal.

IV. Physical Properties of Base Metal

On the $^1/_2$ inch and $1^1/_2$ inches thick plates tensile and bend tests are to be made to determine the physical properties of the plates and the effect of gage on the physical properties. These tests will be done in the conventional manner conforming to the A. S. T. M. test for plate. Material to be as-rolled and normalized.

V. Physical Properties of Welded Joint

Using the 1-inch plate a welded test plate is to be prepared in accordance with the A. S. M. E. specification for unfired pressure vessels and subjected to the requirements of paragraph U-68 including the reduced tensile test, free bend, X-ray, and in addition the tensile impact. Material to be as-rolled and stress relieved.

VI Gas Cutting

Gas cuts will be made in each of the steels in all three gages at a time when specimens are to be removed from the large plates for the various weld tests. The piece being removed should be made sufficiently large so that a piece containing the gas-cut edge may be sawed off for test purposes.

All gas cutting should be done by machine cutting. At least two cuts should be made in each gage, one at the slowest and one at the fastest speed which would ordinarily be used for cutting. In every case the temperature of the base metal should be 70° F. (room temperature) when the cuts are started. The gas-cut surface should be examined by the magnaflux method for cracks. The hardness of the heat-affected zone should be determined by grinding angularly from the cut surface to the unaffected stock. If cracks are found, or the hardness exceeds 300 Brinell, additional cuts should be made on preheated base metal.

VII. Additional Weldability Tests

Sufficient material has been provided in the proposed sizes of plates to conduct such additional tests as may be proposed by coöperating members of the Welding Research Committee. For example, one of the members has proposed to heat treat cubes of each of the steels at 1800° F. and quench in a liquid medium in order to determine the relative hardening effects in the series of carbon manganese steels. Another member uses a Tee-bend test to determine the weldability of steel. In this test an upstanding bar is welded to a through plate of the material undergoing test by means of fillet welds on each side of the bar. After welding the test piece is bent in a standardized form of jig to determine the angle of bend, through which the test piece may be deformed before failure occurs.

In addition it is believed desirable for interested members of the Committee to conduct weldability tests on this series of steels to simulate the conditions encountered in gas welding, union-melt welding and other processes.

Material is to be available for tests approved by the Committee, such as Tee-bend, etc.

VIII. Inter-Relation of Variables

In order to restrict the number of tests contemplated in the hardness test described in Section II, a number of important variables have been fixed arbitrarily at values which are considered normal in metallic arc-welding practice. It is recommended that a separate research program be undertaken on one or two steels selected from the series to determine the inter-relation of variables which affect the weldability of a steel.

In this study it is proposed that automatically deposited weld beads be used in a manner similar to that described under Section II. The following variables should be studied as regards their effect on hardness adjacent to a weld:

1. Welding speed.
2. Welding amperage.
3. Electrode size.
4. Type of electrode coating.
5. Arc height.
6. Preheat temperature.
7. Heat treatment after welding.
8. Multiple beads.

The test agenda for this investigation has not been worked out by the Subcommittee, but should be given careful consideration after proposal to conduct this work

is favorably received by the Committee. In view of the fact that the number of variables is large, the limits to be studied in connection with each variable and the number of steps in a series should be carefully worked out in order to determine the amount of material needed to conduct the investigation.

Although the above tests would consume time and money outside of this Committee work, it is believed that information pertaining to these matters would be extremely valuable. Therefore, any one desiring to take any part in this group may obtain the material, provided the results are forwarded to the Committee.

SOME NOTES ON MONEL* ARC WELDS

By F. G. FLOCKE† AND J. G. SCHOENER†

WHILE in previous papers the authors have always presented the "how" of welding Monel and nickel, this paper will present one angle of the monel welding picture, the end result, viewed from the standpoint of physical properties of deposited weld metal. Earlier papers have quite naturally discussed only technique and method, with occasional reference to quality, because changes were occurring as rapidly in Monel and nickel welding as they were happening in steel welding. In "The Electric Welding of Monel and Nickel," a paper presented by the authors in 1936 before the joint meeting of the American Society of Mechanical Engineers and the AMERICAN WELDING SOCIETY, the physical properties were not discussed at very great length. With a further twelve months of experience in field and laboratory to draw from, it is possible to present a picture detailing the results and drawing conclusions therefrom on electric welds in Monel in thicknesses of $^1/_8$ in. to $^3/_4$ in.

The data available fall into five natural divisions:

I. Physical properties of Monel sheet and plate.
II. Physical properties of Monel to Monel welds in the flat position.
III. Physical properties of Monel to Monel welds in flat, vertical and overhead positions.
IV. Physical properties of Monel to steel welds.
V. Physical properties of high strength Monel welds.

I. PHYSICAL PROPERTIES OF MONEL SHEET AND PLATE

To serve as a base line for comparison for later weld data, the properties of Monel sheet and plate are given below. The lighter gages of Monel—in sheet thicknesses—are furnished in the soft condition, for forming, stamping, etc., prior to welding. Plate heavier than $^1/_4$ in. is available in the as-rolled temper (the hardness varying inversely with the thickness), as annealed material, and as a "low temperature finish" plate used where high strengths in relatively thick sections are desired. The ranges of physical properties available are given in Table 1.

For Monel structures which need not meet the requirements of the Unfired Pressure Vessel Codes, the following values for the allowable working stresses may be used, where the maximum temperature is 700° F.

Table 2—Allowable Working Stresses for Monel Plate

Minimum of Specified Range of the Tensile Strength of the Material in Lb./Sq. In.	Maximum Allowable Working Stress in Lb./Sq. In.
70,000	14,000
75,000	15,000
80,000	16,000

The following joint efficiency factors may be used for metallic arc-welded joints, except where lower values are required by code:

Table 3—Joint Efficiencies

Type of Joint	Joint Efficiency Factor
Double butt welded joint	0.90
Single welded butt joint with backing-up strip	0.90
Single welded butt joint, without backing-up strip	0.80
Double full-fillet lap joint	0.70
Single full-fillet lap joint, with plug welds	0.70
Single full-fillet lap joint	0.60

Where structures are required to meet the specifications of the Unfired Pressure Vessel Code, some modifications of the above values may be necessary.

II. PHYSICAL PROPERTIES OF MONEL TO MONEL WELDS IN THE FLAT POSITION

Certain fabricators, desirous of building heavy Monel equipment, had the usual insurance shop and welder qualification tests carried out in their plants, prior to beginning welding.

Table 1—Physical Properties of Monel Sheet and Plates

	Yield Point 0.2% Set, psi	Tensile Strength, psi	Elongation, %	Brinell Hardness, 3000 Kg.
Sheet annealed	25–35,000	65– 80,000	40–25	120–175
Plate annealed	25–45,000	70– 85,000	60–50	125–170
As-rolled	40–90,000	80–110,000	55–25	150–220
Low temperature finish	64,500	90,000	32	

Table 4—Physical Properties of $^5/_{16}$-In. Monel Arc Welds

	Yield Point, psi	Ultimate Tensile, psi	Elong. in Free Bend, %	Failure in
Full section tensile	35,800	84,235		Center of weld
Reduced section tensile	32,100	80,655		Center of weld
Free bend			40	No failure

Nick break—Fine structure, no slag inclusions, good fusion, numerous very small pockets.

* "Monel" is a registered trade-mark applied to an alloy containing approximately two-thirds nickel and one-third copper. Presented at Annual Meeting, AMERICAN WELDING SOCIETY, Atlantic City, Oct. 1937. A Contribution to the Industrial Research Division, Welding Research Committee.

† International Nickel Co.

Table 5—Physical Properties of 3/8-In. and 7/16-In. Stress-Relieved Monel Metallic Arc Welds*

	3/8-In. Monel Plate			7/16-In. Monel Plate		
	Tensile Strength, Lb./Sq. In.	Ductility, Per Cent	Remarks	Tensile Strength, Lb./Sq. In.	Ductility, Per Cent	Remarks
Full section tensile specimen	78,500	..	Break in weld	77,200	..	Break in weld
Reduced section tensile specimen	77,600	..	Break in weld	79,800	..	Break in weld
Free bend, face of weld in tension, 180 deg. bend	....	44.4	No failure	....	38.8	No failure
Free bend, reverse of weld in tension, 180 deg. bend	....	50.0	No failure	....	37.5	No failure
Nick-break test			Good			Good
X-ray examination			Good			Good

* Courtesy of M. W. Kellogg Co.

The usual butt joint test plate of 5/16 in. Monel was welded up, to provide for the short and long gage tensile, free-bend and nick-break specimens. A single vee was used, with about a 70° total included angle, and about 1/16 in. to 3/32 in. space at the bottom, no backing plate. The first bead, deposited with a 1/8 in. Monel electrode was followed by two layers deposited by a 5/32-in. electrode. No heat treatment followed the welding.

Similar single vee metallic arc welds were made up in 3/8-in. and 7/16-in. plate, but before physical testing were subjected to X-ray examination and a stress relief anneal at the same temperature used for steel structures, 1100–1200° F. and held for one hour per inch of plate thickness.

The results of a hardness survey on a stress relieved Monel weld, the fusion zone and plate area remote from the weld is given in Table 6.

Table 6—Hardness Survey of 3/8-In. Monel Welds*†

	As-welded	After Stress Relieving at 1150° F.
Center line of weld		
Top	159	156
Center	159	165
Bottom	141	141
Junction of weld and base metal	159	154
Center of heat-affected zone	153	153
Base metal remote from weld	144	144

* Courtesy of M. W. Kellogg Co.
† Readings taken from Rockwell and converted to Brinell.

The welding of a 3/4-in. Monel plate was carried out using a double vee with 70–75° included angles instead of a U groove. This test was for insurance shop qualification prior to fabrication of a 6 foot diameter drum. A space at the base of the vees was necessary to permit of penetration of weld metal during the first pass and so also require a minimum of chipping when beginning the weld on the second side. Weld metal was deposited with a 5/32-in. electrode. Table 7 gives values of the 3/4-in. Monel welds, in the as-welded condition.

Table 7—Physical Properties of 3/4-In. Monel Metallic Arc Welds

	Ultimate Tensile, psi	Elongation, %	Remarks
Reduced section tensile	84,622		Break in weld
Reduced section tensile	84,210		Break in weld
Free bend		60	No failure
Nick breaks (two specimens)			O.K.

III. PHYSICAL PROPERTIES OF MONEL TO MONEL WELDS IN FLAT, VERTICAL AND OVERHEAD POSITIONS

There is an increasing use of electric welding for the position welding of Monel, and a definite test program was initiated to obtain accurate data. Many physical tests made later, confirmed early findings.

In the particular test in question, the butt joints made in 3/8-in. and 3/16-in. Monel had a butt strap or backing strip held tightly against the root side of the 70° beveled butt joint. A 3/16-in. space at the base of the vee was sufficient to permit use of a 5/32-in. Monel electrode on 3/8-in. plate and a 5/32-in. space for a 1/8-in. electrode on 3/16-in. plate. Each plate is welded in the required position, and in the case of vertical welding, the welding was started at the bottom and worked upward. Welding on butt joints is done from one side only. After top and bottom surfaces of the weld were machined flush with the plate, the test plates were sectioned for short and long gage tensiles, millings for chemical analysis, and for two bend test specimens, with the bends through the weld and parallel to the direction of welding. The one bend specimen is bent in such a way as to stress the root or penetration side of the weld to determine the completeness of fusion at the root of the vee. This bend will also open up any porosity or disclose any tendency to trap slag. The second bend specimen is bent to put the face side of the weld in tension for the purpose of determining ductility, qualitatively and quantitatively, to establish the completeness of fusion or disclose any tendency to undercut.

Table 8—Tensile and Bend Tests of Position Welds in 3/16-In. and 3/8-In. Monel

	3/16-In. Monel Plate-Butt Joint 1/8 In. Diam. Electrode			
	Ultimate Strength, psi	Fracture	Bend Tests Face	Bend Tests Root
Long Gage Tensile				
Flat	71,680	In weld	O.K.	O.K.
Vertical	70,865	In weld	O.K.	O.K.
Overhead	71,392	In weld	O.K.	O.K.
Short Gage Tensile				
Flat	76,962	In plate	O.K.	O.K.
Vertical	73,595	In weld	O.K.	O.K.
Overhead	71,913	In plate	O.K.	O.K.
	3/8-In. Monel Plate-Butt Joint 5/32 In. Diam. Electrode			
	Ultimate Strength, psi	Fracture	Bend Tests Face	Bend Tests Root
Long Gage Tensile				
Flat	75,628	In weld	O.K.	O.K.
Vertical	72,880	In fusion line	O.K.	O.K.
Overhead	77,092	In fusion line	O.K.	O.K.
Short Gage Tensile				
Flat	75,837	In weld	O.K.	O.K.
Vertical	76,018	In fusion line	O.K.	O.K.
Overhead	76,525	In fusion line	O.K.	O.K.

A specimen for a bend test is originally flat and straight, but when bending is completed the piece is U shaped with sides parallel. When a $^3/_8$ in. thick specimen is bent in a jig around a $^3/_4$ in. radius pin to throw a uniform stress into the plate and weld alike, any slight defect will naturally open up quickly. A defect no longer than $^1/_8$ in. in any dimension is tolerated. In one specification covering all position welding of Monel the minimum tensile requirement in any position is 70,000 lb. per sq. in. while the maximum allowable defect in face and root bend test specimens is $^1/_8$ in. long. The values in Table 8 show how the welds fulfill this specification.

Fillet welds must also be made in position as part of this particular electrode approval test, to determine (*a*) whether any porosity or cracking develops during welding; (*b*) cross section, really a macro specimen, to show penetration, contour of bead, undercutting, etc. These two examinations are made in lieu of a more expensive tensile or tension-impact test.

IV. PHYSICAL PROPERTIES OF MONEL TO STEEL WELDS

Oftentimes in the building of pressure vessels, it becomes necessary to weld steel parts to Monel. In one case, a large rotary drying drum, 6 ft. in diameter by 6 ft. long was to be built of Monel because of resistance to a particular corrosive. The heads of the drum, not coming into contact with the liquid might easily be made of steel, if some definite test could establish the soundness and strength of the joint. Tests, again under the supervision of insurance engineers, were carried out on $^3/_8$-in. and $^3/_4$-in. Monel joined to equal thicknesses of medium carbon steel. The $^3/_8$-in. welds were of the single vee type while a U groove was used for the $^3/_4$-in. Monel to steel welds.

Table 9—Physical Properties of Arc Welds Between Monel and Steel, Welds Made with Monel Electrodes

	$^3/_8$-In. Monel to Steel Welds		
	Tensile Strength, psi	Ductility Free Bend Test, %	Remarks
Reduced section tensile	64,851		Break in steel
Full section tensile	61,871		Break in steel
Free-bend test		41.86	No failure
Nick-break test			O.K.; fine grain, no defects

	$^3/_8$-In. Monel to Steel Welds		
	Tensile Strength, psi	Ductility Free Bend Test, %	Remarks
Reduced section tensile	64,410		Break in steel
Reduced section tensile	66,755		Break in steel side fusion line
Free-bend test		28	No failure
Free-bend test		28	No failure
Nick-break test			1 pocket, $^1/_{16}$ in. x $^1/_4$ in.
Nick-break test			O.K.

V. PHYSICAL PROPERTIES OF HIGH STRENGTH MONEL WELDS

In an effort to develop very high strengths in fabricated structures of $^1/_2$-in. and 1-in. Monel plate, a minimum proportional limit (0.00% set) 55,000 psi was specified together with a 90,000 psi ultimate strength. Monel plate of this strength could be made by finishing the hot-rolled plate at a lower temperature, really adding some cold work to a hot-rolled plate. Since the problem of joining a plate of these strengths by electric welding had not come up before, it required some investigation.

A special Monel electrode was developed for making the welded joints in these high tensile plates. A variety of Monel known as "K" Monel is alloyed with aluminum, and is hardenable not only by cold work, but by heat treatment and the effects are additive. Electrodes of this material were used, with welds subjected to heat treatment (1077° F. for three hours) to improve tensile and yield point values, and not disturb the ductility. The following values are two of many available and will serve as an illustration of the physicals which can be developed.

Table 10—Physical Properties of High Strength Monel Welds*

Weld Specimen	Proportional Limit, Lb./Sq. In.	Yield Strength (0.2% Set), Lb./Sq. In.	Tensile Strength, Lb./Sq. In.	Elong. in 1 In., Per Cent
1	33,200	46,000	93,440	42.0
2	26,000	45,200	93,120	41.1

* Courtesy of Watertown Arsenal.

An interesting test piece of definite practical value, a $6^1/_2$-in. H-beam, was fabricated of $^3/_8$-in. Monel by arc welding. In making up the welded beam, it was planned to observe distortion during welding, and stress relieving, and ease of maintaining tolerances during machining. To determine the quality of the welded beam, it was to be tested to destruction in addition to taking the necessary X-rays. The $28^3/_4$ in. long beam was loaded in the center and supported at both ends on 28 in. centers. It withstood an ultimate load of 230,000 lbs. and yielded at a load of 150,000 lbs. This amounted to a yield point in the weld metal of approximately 42,000 psi.

SUMMARY

The strengths of metallic arc-welded joints in Monel up to $^3/_4$ in. in thickness are very satisfactory. A minimum tensile strength of 70,000 psi is regluarly met not only when welding in the downhand position, but when depositing weld metal in vertical and overhead positions. Welding in the vertical position is done upward.

A minimum value of 30% elongation in either jig bend or free bend is being met in arc welds made between Monel and Monel, in welds made in any position.

X-rays of Monel welds from $^3/_8$ in. to $2^1/_2$ in. in thickness attest the soundness of Monel welds.

Where Monel must be joined to mild steel, this can be done by metallic arc welding with a Monel electrode. In every case, fractures in tensile tests were in the carbon steel plate, indicating that the Monel weld strength was in excess of the tensile strength of the carbon steel.

When tensile strengths of the order of 90,000 psi are required in welded Monel joints, these are available where completed structures can be subjected to heat treatment.

REPORT OF SUBCOMMITTEE* on Welding of Low-Alloy Steels

By J. H. CRITCHETT†

ALTHOUGH low-alloy steels for general structural and engineering purposes have been known and used by the engineering profession for several decades, it was not until the more recent developments of the low-carbon balanced alloy varieties that the problem of weldability of such steels became a matter of industrial importance. The newer steels differ from those used in the past in two important essentials, both of which make for conservative, permanent light weight construction. These are weldability and corrosion resistance, and the combined properties of these steels are so attractive that practically every steel company of importance is now producing such steel. The various brands differ widely in chemical analysis, but conform to the general principle of relatively low carbon with balanced alloying additions. Information on the properties and weldability of such steels has not been lacking in the past few years, but such data are scattered through the literature, and in most instances information on the weldability is given along with a discussion of other properties. Accordingly, this committee set as its objective the compilation and correlation of the data in such form that the steels may be more readily compared and in such a manner as to emphasize the factors entering into the problem of welding. The resulting compilation is herewith presented in the accompanying tables. For clarity and simplicity the data have been restricted to butt joints fusion welded.

For ready reference Table A gives the type and analysis of the steels in question together with the source of the information as subsequently reported in Table B. In Table B those physical properties pertinent to the weldability are listed together with the type of welding involved. In addition, the steels are listed with a serial number, starting at 100, 200 and 300, respectively. An attempt has been made to list in the 100 series those steels which may be designated as foolproof from the welding standpoint. In general, these steels contain less than 0.15% carbon. In the 200 series are listed those steels which are moderately air-hardening under average welding conditions. Attention must be given to the ductility of the zone adjacent to the weld in these steels. When butt welded they may or may not require a stress-relieving or tempering treatment, and when fillet welded will generally develop a very narrow zone of reduced ductility. This ductility may or may not be sufficient, depending upon the character of the structure involved. In general, these steels contain less than 0.30% carbon, but may contain slightly more, depending on the alloying constituents. In the 300 series are listed those steels in which the zone next to the weld undergoes sufficient loss of ductility, so that it becomes very serious from the engineering standpoint. Such steels definitely require stress relieving, unless very special conditions are involved. They generally contain 0.30% carbon or more, but may contain slightly less, depending on the alloying constituents.

Obviously, any grouping of steels on a broad basis such as the above will fail to take into account certain special conditions and special cases. For example, the chromium-molybdenum S.A.E. X4130 steel is listed in the 300 series, and it is obviously true that welded plate of this analysis must be stress relieved. However, by contrast aircraft tubing of this analysis is free from the difficulty in question because in proportion to the thickness of the material a large amount of heat is used in the welding operation, and the hardening tendency, therefore, inhibited to a marked degree. This, however, carries with it a well developed and somewhat special technique and may be regarded as the exception that proves the rule.

It will be noted that the information in Tables A and B results from a study of the literature. Subsequent to this study a questionnaire was sent to the leading producers and users of low-alloy steels. Further information more recent in character than that in Tables A and B was obtained from that questionnaire, and this information is compiled in Tables C and D.

Naturally, there is divergence in the ideas of the various testing engineers as to the methods of testing the welded joints and reporting the results. In many instances it has been necessary to select data from the information obtained with a view to brevity and conformity. For example, the information obtained from one source was in the form of percentage deviation charts and mean values were selected from these charts for the figures given in Tables C and D. Again, hardness measurements have been reported as Vickers, Brinell or Rockwell. In the interest of conformity and for purposes of comparison these have been all converted to Rockwell *B*. In view of the fact that the original sources are designated in every case, those interested in more precise information than obtainable from the conversion figures may study the data from the original sources.

It is significant that the foolproof welding steels listed under the 100 series almost regardless of the method of welding never show a Rockwell *B* hardness of more than 96 either in the weld proper or in the metal adjacent to the weld. This hardness corresponds to approximately 200 Brinell. The steels in the 200 and 300 series when welded without special precautions invariably show a hardness greater than this amount. This leads to a very simple but dangerous method of classifying the low-alloy steels from the standpoint of weldability. The method is simple in that all that is required is a hardness exploration across the joint. It is dangerous because hardness does not necessarily mean lack of ductility, and the conclusions as to the weldability should be based on ductility and not on hardness. In fact, the major initial purpose of the low-alloy steels is to obtain strength or hardness, without corresponding loss of ductility.

Consider carbon steel with 0.22% carbon, gas welded, in $^3/_4$-inch plate. This attains a Rockwell *B* hardness of

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82 immediately adjacent to the weld, and this hardness is accompanied by a drop in impact strength to approximately 8 ft.-lb. whereas the low-alloy steels with a Rockwell *B* hardness of approximately 82 adjacent to a gas weld show an impact strength from 22 to 30 ft.-lb. and substantially retain this impact strength as the hardness approaches 96. To further illustrate this point, the average value for plain 0.15% carbon steel in the as-rolled condition has been quoted as Rockwell *B* 75, with 32% elongation and 65% reduction of area. The same source quotes chromium-vanadium steel with 0.15% carbon as Rockwell *B* 86, with 30% elongation and 68% reduction of area. In other words, these steels have substantially the same ductility usually measured on tensile test, but the alloy steel shows an increase in Rockwell hardness from 75 to 86. Again, if heat treated to Rockwell *B* hardness of 94 the plain 0.15% carbon steels are quoted at 20% elongation and 50% reduction of area, whereas the chromium-vanadium 0.15% carbon steels heat treated to the same hardness, *B* 94, show 30% elongation and 62% reduction of area. Obviously, hardness is no more than a very rough qualitative index of ductility and may be highly misleading.

Those who have not devoted themselves to this special

TABLE A

ANALYSIS

No.	Name	C	Mn	Si	P	Cr	Ni	Mo	V	Cu	Reference
101	Cor-Ten	0.09	0.22	0.508	0.10–0.20	0.97	...	..	...	0.38	Am. Weld. Soc. Jl., **14**, pp. 2–8, Sept. 1935, Gibson.
102	Cr-Cu-P	0.12	0.40	0.76	0.16	1.08	...	..	...	0.39	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner.
103	Chromephos Special Cu-Ni-P & 0.35 Cr	0.08	0.48	0.130	0.118	0.35	0.50	..	...	1.06	*A. I. M. E.*, T. P. 697, Feb. 1936, Epstein, Nead & Halley.
104	Cromansil	0.12–0.15	1.1–1.4	0.7–0.8	...	0.4–0.6	...	..	...	..	*Iron Age*, **138**, p. 32, Dec. 31, 1936, Jennings.
105	Cu-Ni-Cr	0.07	0.42	0.224	0.010	0.69	0.45	..	...	0.80	*A. I. M. E.*, T. P. 697, Feb. 1936, Epstein, Nead & Halley.
106	Nickel	...	...	...	...	..	1.0–2.0	..	...	..	*Weld. Engr.*, **21**, pp. 22–24, July 1936, Larson.
107	Yoloy	0.08	...	...	...	..	1.99	..	...	1.02	Am. Weld. Soc. Jl., **14** pp. 2–8, Sept. 1935, Gibson.
108	R.D.S.	0.09	0.85	0.03	0.02	..	1.08	0.10	...	1.60	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner.
109	R.D.S.	0.095	...	...	0.04 (max.)	..	0.75	0.07	...	1.44	*Iron Age*, **138**, p. 35, Dec. 31, 1936, Jennings.
110	Cu-Ni-P	0.08	0.48	0.130	0.120	..	0.47	..	...	1.05	*A. I. M. E.*, T. P. 697, Feb. 1936, Epstein, Nead & Halley.
111	Mn-Mo (Manganese-moly.)	0.12	1.00	0.21	0.03	..	...	0.49	...	..	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner.
201	Cr-V	0.10–0.20	0.3–0.6	0.2–0.3	0.04	0.8–1.1	...	..	0.15–0.20	..	*Iron Age*, **139**, pp. 27–28, Jan. 14, 1937, Jennings.
202	Cr-V	0.30	...	...	...	0.8–1.10	...	..	0.15–0.20	..	*Weld. Engr.*, **21**, pp. 22–24, July 1936, Larson.
203	Nickel	0.30	...	...	...	..	3.0–3.8	..	...	..	*Weld. Engr.*, **21**, pp. 22–24, July 1936, Larson.
204	3½% Nickel	0.1–0.2	0.30–0.60	0.15–0.30	0.04	..	3.25–3.75	..	...	..	*Iron Age*, **138**, p. 32, Dec. 31, 1936, Jennings.
205	3½% Nickel	0.23	0.64	0.18	...	..	3.27	..	...	..	Am. Weld. Soc. Jl., **15** (Suppl.), Oct. 1936, Warner.
206	Nickel	<0.30	...	...	...	..	2.0–3.0	.	...	..	*Weld. Engr.*, **21**, pp. 22–24, July 1936, Larson.
207	2% Ni (Ni boiler plate)	0.22	0.62	0.14	...	..	2.09	..	...	..	Am. Weld. Soc. Jl., **15** (Suppl.), p. 23, Oct. 1936, Warner.
208	Yoloy	0.22	...	...	...	..	1.98	..	...	0.92	Am. Weld. Soc. Jl., **14**, pp. 2–8, Sept. 1935, Gibson.
209	R. D. S.	0.23	0.72	0.02	0.02	..	0.79	0.15	...	1.56	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner.
210	R. D. S.	0.2	...	...	0.04 (max.)	..	0.75	0.76	...	1.30	*Iron Age*, **138**, p. 35, Dec. 31, 1936, Jennings.
211	R. D. S.	0.23	...	...	...	..	0.75	0.16	...	1.30	Am. Weld. Soc. Jl., **14**, pp. 2–8, Sept. 1935, Gibson.
212	Manganese	<0.30	1.0–1.5	...	...	..	...	..	...	..	*Weld. Engr.*, pp. 22–24, July 1936, Larson.
213	Mn-V	0.19	1.62	0.25	0.40	..	...	..	0.17	..	*Iron Age*, **139**, pp. 28–29, Jan. 14 1937, Jennings.
214	Mn-Mo (Manganese-moly.)	0.17	1.57	0.43	0.02	..	...	0.38	...	..	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner.
215	Mn-V	0.15	1.29	0.20	0.04	..	...	..	0.11	..	*Industry & Welding*, **8**, pp. 52–53, Feb. 1936.
301*	Cr-Mo (S.A.E. X4130)	0.30	0.45	...	0.40 (max.)	0.9	...	0.17	...	..	*Iron Age*, **139**, p. 28, Jan. 14, 1937, Jennings.
302	3½% Nickel	0.35	0.62	0.16	...	0.22	3.27	..	...	..	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner.
303	Man-Ten	0.25–0.35	1.25–1.70	0.15 (min.)	0.40	..	...	..	...	..	*Iron Age*, **138**, p. 33, Dec. 31, 1936, Jennings.
304	Man-Ten	0.27	1.54	0.20	...	..	...	..	...	..	Am. Weld. Soc. Jl., **14**, pp. 2–8, Jan. 1935, Gibson.
305	Mn-Cu (Krupp 52)	0.30	1.40	0.20	...	..	...	..	...	0.25	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner.
306	Cu-Mo	0.29	0.74	0.24	0.03	..	...	0.22	...	0.35	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner.

* When welded with aircraft technique this steel falls in the 100 series.

TABLE B

No.	Name	Condition	Type Welding	Fracture	Y. S. M / Sq. In.	T. S. M / Sq. In.	% El. in 2 Inches	% R. A.	Charpy Impact Ft.-Lb.
101	Cor-Ten	As-rolled			51	74	41	55	
		As-welded	E	P	50	75	23***	61	
102	Cr-Cu-P (Cor-Ten)	As-rolled			44	76	59**		873 (T. I.)
		Stress relieved			46	75	59**		836 (T. I.)
		As-welded	E—C-Mo		46	85	25**		744 (T. I.)
		Stress relieved	E—C-Mo		41	78	26**		707 (T. I.)
103	Cu-Ni-P and 0.35% Cr (Chromephos Special)	As-rolled[1]			72	82	22***		28
		Norm. 1650° F.[1,2]			63	77	21***		31
		As-rolled[3]			70	80	23***	65	42
		Norm. 1650° F.[3]			63	78	23***	71	44
		As-welded[1]	E—C-Mo	W	60	80	10***		
		As-welded[1]	E—C-Mo	P	58	82	19***		
		Machined[1]	E—C-Mo	W		64	1***		
		Machined[1]	E—C-Mo	W		62	1***		
		As-welded[3]	E—C-Mo	P	69	79	21***	67	
		As-welded[3]	E—C-Mo	P	67	79	20***	65	
		Machined[3]	E—C-Mo	P	68	80	19***	61	
		Machined[3]	E—C-Mo	W	65	65	13***	21	
		As-welded	G—(Base Material)	P	69	82	21***		
		As-welded	G—(Base Material)	P	68	81	21***		
		Machined	G—(Base Material)	W	69	76	8***		
		Machined	G—(Base Material)	W		48	0***		
		As-welded	G—(Base Material)	P	66	80	19***	66	
		As-welded	G—(Base Material)	P	65	79	20***	62	
		Machined	G—(Base Material)	W	66	66	1***	7	
		Machined	G—(Base Material)	W	64	78	8***	11	
104	Cromansil	As-rolled			55–60	80–90	20–28	50–62	
		As-welded	E—Low C		45	78	24		
		Stress relieved	E—Low C		42	75	26		
		As-welded	E—Moly alloy		60	91	22		
		Stress relieved	E—Moly alloy		56	88	26		
105	Cu-Ni-Cr (Chromecop)	As-rolled[1]			65	75	24***		34
		Norm. 1650° F.[1,2]			52	68	25***		34
		As-welded	E—C-Mo	P	61	74	20***		
		As-welded	E—C-Mo	P	61	74	22***		
		Machined	E—C-Mo	W		46	0***		
		Machined	E—C-Mo	W		46	0***		
		As-welded	G—(Base Material)	P	62	75	17***		
		As-welded	G—(Base Material)	P	60	74	17***		
		Machined	G—(Base Material)	P	65	73	19***		
		Machined	G—(Base Material)	P	65	73	20***		
106	Nickel	As-rolled			40–50	60–70	40–50		
		Welded and stress relieved	E		45–55	60–75	25–35		
107	Yoloy	As-rolled			54	67	29	62	
		As-welded	E	P	57	63	29	70	
		As-welded	E	P	65	69	26	66	
		Stress relieved	E	P	80	83	24	57	
		Stress relieved	E	W	72	84	20	37	
		Stress relieved	E	P	57	71	29	64	
		Stress relieved[4]	E	P	70	73	29	64	
		Stress relieved	E	P	55	68	35	62	
		Stress relieved	E	P	53	68	33	60	
		As-welded	E	P	86	95	27	42	
		As-welded	E	P	85	92	27	44	
108	R. D. S.	As-rolled			41	87	47**		740 (T. I.)
		Stress relieved			50	73	55**		706 (T. I.)
		As-welded	E—C-Mo		44	86	33**		688 (T. I.)
109	R. D. S.	As-rolled			68	82	33	54	
		As-welded	E—C-Mo*		70	85	29		
110	Cu-Ni-P (HI Steel)	As-rolled[1]			73	80	23***		28
		Norm. 1650° F.[1,2]			62	75	21***		29
		As-rolled[3]			69	77	22***		42
		Norm. 1650° F.[1,3]			63	75	25***		46
		As-welded	E—C-Mo	W	70	78	10***		
		As-welded	E—C-Mo	P	69	80	18***		
		Machined	E—C-Mo	W		59	0***		
		Machined	E—C-Mo	W		74	1***		
		As-welded	E—C-Mo	P	67	77	20***	66	
		As-welded	E—C-Mo	P	67	78	20***	65	
		Machined	E—C-Mo	P	66	76	12***	41	
		Machined	E—C-Mo	W	65	78	2***	27	
		As-welded	G—(Base Material)	P	68	79	15***		
		As-welded	G—(Base Material)	P	69	80	16***		
		Machined	G—(Base Material)	W	67	75	7***		
		Machined	G—(Base Material)	W	67	67	3***		
		As-welded	G—(Base Material)	P	65	78	21***	63	
		As-welded	G—(Base Material)	P	65	78	21***	62	
		Machined	G—(Base Material)	P	65	73	17***	48	
		Machined	G—(Base Material)	W	66	74	9***	20	
111	Mn-Mo (Manganese-moly.)	As-rolled			37	84	54**		780 (T. I.)
		Stress relieved			37	80	51**		800 (T. I.)
		As-welded	E—C-Mo		52	86	30**		712 (T. I.)
		Stress relieved	E—C-Mo		50	84	38**		788 (T. I.)

TABLE B (*Continued*)

No.	Name	Condition	Type Welding	Fracture	Y. S. M / Sq. In.	T. S. M / Sq. In.	% El. in 2 Inches	% R. A.	Charpy Impact Ft.-Lb.
201	Cr-V (SAE—6115)	As-rolled			60–70	80–90	25–35		
		As-welded	E—C-Mo*		65	90	22	46	
202	Cr-V	As-rolled			55–65	85–95	25–35		
		Welded and stress relieved	E		65–80	85–100	15–20		
203	Nickel	As-rolled			45–60	70–80	30–40		
		Welded and stress relieved	E		50–65	70–85	20–30		
204	3½% Nickel	As-rolled			55–60	80–90	20–25	50–55	
		As-welded	E—Low C bare*[14]		40–45	60–70	8–10	5–10	
		As-welded	E—Low C coated*[14]		40–45	75–80	10–15	20–25	
		As-welded	E—3½% Ni coated*[14]		45–55	90–95	15–20	18–25	
		As-welded	E—2% Ni coated*[14]		40–45	80–85	15–20	20–25	
		As-welded	E—Ni-Moly*[14]		45–50	80–85	15–20	20–25	
205	3½% Nickel	As-rolled			50	90	40**		750 (T. I.)
		Stress relieved			57	84	50**		769 (T. I.)
		As-welded	E—C-Ni-Mo		55	95	17**		600 (T. I.)
206	Nickel	As-rolled			45–60	80–100	25–35		
		Welded and stress relieved	E		65–80	85–100	15–20		
207	2% Ni (Ni boiler plate)	As-rolled			42	80	50**		790 (T. I.)
		Stress relieved			50	75	60**		830 (T. I.)
		As-welded	E—C-Ni-Mo		50	85	23**		670 (T. I.)
208	Yoloy	As-rolled			64	95	26	57	
		As-welded	E	P	86	95	27	42	
		As-welded	E	P	85	92	27	44	
		Stress relieved[11]	E	W	83	90	9	17	
		Stress relieved[11]	E	W	79	101	19	33	
		Stress relieved[12]	E	W	69	88	17	24	
		Stress relieved[12]	E	W	64	81	18	38	
		Stress relieved[13]	E	W	65	80	14	16	
209	R. D. S.	As-rolled			58	105	40**		773 (T. I.)
		Stress relieved			60	89	48**		778 (T. I.)
		As-welded	E—C-Mo		53	99	22**		581 (T. I.)
210	R. D. S.	As-welded[7]	E—C-Mo		81	96	29		
		Stress relieved	E—C-Mo		94	104	22		
211	R. D. S.	As-rolled			70	90	18		
		As-welded	E—Mo coated		81	96	[9]	29	
		Stress relieved	E—Mo coated		94	105	[10]	29	
212	Manganese	As-rolled			40–60	60–90	25–35		
		Welded and stress relieved	E		50–75	65–95	15–30		
213	Mn-V	As-rolled			70–80	100–110	20–30	40–50	
		As-welded[8]	E—C-Mo		66	95	22	35	
214	Mn-Mo (Manganese-moly.)	As-rolled			36	104	42**		890 (T. I.)
		Stress relieved			47	92	46**		800 (T. I.)
		As-welded	E—C-Mo		56	95	22**		614 (T. I.)
		Stress relieved	E—C-Mo			93	37**		204 (T. I.)
215	Mn-V	As-welded	E—Mn-V	P	68	88	18	39	
		Stress relieved	E—Mn-V	P	67	87	21	51	
301	Cr-Mo (SAE X4130)	As-rolled			60–70	100–110	20–30	50–60	
		As-welded	E—C-Mo*		60	80	28		
		Stress relieved	E—C-Mo*		55	75	34		
302	3½% Nickel	As-rolled			55	107	35**		810 (T. I.)
		Stress relieved			61	100	40**		820 (T. I.)
		As-welded	E—C-Ni-Mo		55	104	21**		560 (T. I.)
303	Man-Ten	As-rolled			55–65	80–90	25–30	40–50	
		As-welded	E—Mo alloy[6]		53	90	15[4]		
		Stress relieved	E—Mo alloy[6]		51	88	20[5]		
304	Man-Ten	As-rolled			56	92	20***	47	
		As-welded	E	2 in W—1 in P	55	88	15	58	
305	Mn-Cu (Krupp 52)	As-rolled			45	91	53**		934 (T. I.)
		Stress relieved			40	80	58**		861 (T. I.)
		As-welded	E—C-Mo		50	97	27**		726 (T. I.)
		Stress relieved	E—C-Mo		35	87	36**		641 (T. I.)
306	Cu-Mo	As-rolled			45	90	40**		810 (T. I.)
		Stress relieved			50	88	42**		820 (T. I.)
		As-welded	E—C-Mo		51	93	37**		697 (T. I.)
		Stress relieved	E—C-Mo		47	87	39**		754 (T. I.)

[1] Gage 0.062 inch.
[2] Air cooled.
[3] Gage 0.125 inch.
[4] 32% free bend.
[5] 40% free bend.
[6] Preheating recommended for heavy sections.
[7] For best weldability C content should be low. For higher C content preheating recommended. Heat treatment after welding recommended.
[8] Preheating beneficial for heavy sections.
[9] Bend 149°.
[10] Bend 127°.
[11] 950° F., 1 hr.
[12] 1200° F., 1 hr.
[13] 1650° F., 1 hr.
[14] Heat treatment after welding recommended.
* Preheating recommended.
** Elong. in 1 inch.
*** Elong. in 8 inches.
E—Electric
G—Gas
T. I.—Tensile Impact
C—Carbon
P—In plate
W—In weld

TABLE C

ANALYSIS

No.	Name	C	Mn	Si	S	P	Cr	Ni	Cu	Mo	V	Source
101X	Cor-Ten	0.09	0.30	0.65	0.04	0.13	0.95	..	0.40	..	..	Carnegie-Illinois Steel Corp.
(*a*)	Cor-Ten	0.10	0.27	0.48	...	0.140	0.89	..	0.43	..	..	U. C. & C. Res. Labs.
(*b*)	Cor-Ten	0.09	0.25	0.49	...	0.140	0.89	..	0.41	..	..	U. C. & C. Res. Labs.
(*c*)	Cor-Ten	0.09	0.37	0.73	...	0.117	0.89	..	0.43	..	..	U. C. & C. Res. Labs.
104X	Cromansil	0.13	1.32	0.78	...	...	0.43	..	0.13	..	..	U. C. & C. Res. Labs.
105X	Mayari R	0.08	0.72	0.40	0.042	0.10	0.56	0.33	0.62	..	..	Bethlehem Steel Company
(*a*)	Mayari R	0.08	0.72	0.40	0.042	0.10	0.56	0.33	0.62	..	..	Bethlehem Steel Company
(*b*)	Mayari R	0.08	0.50	0.10	0.035	0.099	0.25	0.34	0.50	..	..	Bethlehem Steel Company
107X	Yoloy	0.07	0.38	...	...	...	..	1.79	0.92	..	..	A. O. Smith Corporation
(*a*)	Yoloy	0.06	0.35	0.005	...	...	..	1.73	0.93	..	..	Am. Weld. Soc. Jl., **15** (Suppl.), pp. 21–32, Oct. 1936, Warner
(*b*)	Yoloy	0.04	0.36	0.01	...	...	..	1.76	0.91	..	..	U. C. & C. Res. Labs.
(*c*)	Yoloy (max. percentages)	0.10	0.50	0.30	0.05	0.04	..	2.00	1.00	..	..	Youngstown Sheet & Tube Co.
108X	R. D. S.	0.07	0.84	...	...	...	..	0.97	1.45	0.10	..	U. C. & C. Res. Labs.
110X	Hy Steel	0.10	0.61	0.19	0.017	0.102	..	0.62	1.15	..	..	U. C. & C. Res. Labs.
112X	"AW"-70-90	0.15	0.60	Tr	0.03	0.09	..	..	0.42	..	..	Alan Wood Steel Company
206X	Nickel	0.19 – 0.30	0.56 – 1.03	0.14 – 0.28	...	...	..	2.08 – 3.61	..	..	..	Cooperative Com. on Special Steels for Ship Construction.
208X	Yoloy	0.16	0.60	0.20	...	...	..	2.09	1.06	..	..	Am. Weld. Soc. Jl., **15** (Suppl.), p. 21, Oct. 1936, Warner
212X	High Tens. Mn	0.14 – 0.29	1.36 – 1.64	0.04 – 0.18	...	...	..	..	..	..	..	Cooperative Com. on Special Steels for Ship Construction
(*a*)	Man-Ten	0.25	1.50	...	0.04	0.04	..	..	0.22	..	..	Carnegie-Illinois Steel Corp.
214X	Mn-Mo	0.15 – 0.22	0.88 – 1.59	0.09 – 0.44	...	...	..	..	..	0.22 – 0.34	..	Cooperative Com. on Special Steels for Ship Construction
215X	Mn-V	0.14 – 0.20	1.32 – 1.57	0.02 – 0.24	...	...	..	..	..	..	0.10 – 0.18	Cooperative Com. on Special Steels for Ship Construction
216X	Sil-Ten	0.36	0.60	0.20	...	...	..	2.09	1.06	..	..	Am. Weld. Soc. Jl., **15** (Suppl.), p. 21, Oct. 1936, Warner
217X	Cromansil	0.18 – 0.23	1.10 – 1.40	0.65 – 0.85	...	...	0.40 – 0.60	..	..	..	..	Cooperative Com. on Special Steels for Ship Construction

TABLE D

No.	Name	Condition	Type Welding	Fracture	Y.S. M Lb./ Sq. In.	T.S. M Lb./ Sq. In.	% Elong. in 2 Inches	% R. A.	Charpy Impact Ft.-Lb.	Max. Loc. Hardness Over 96 Rock. B
101X	Cor-Ten	As-rolled			50	70	21		40	
(*a*)	Cor-Ten	As-rolled			48	72	46	68		
		As-welded	G—bare	P	44	73	32		23	No
		Stress relieved[1]	G—bare	P	47	72	33		33	No
(*b*)	Cor-Ten	As-rolled			57	74	41	66		
		As-welded	G—bare	P	52	73	25			No
		Stress relieved[1]	G—bare	P	52	73	33			
(*c*)	Cor-Ten	As-rolled			50	77	33	57		
		As-welded	G—bare	P	51	76	24			No
		Stress-relieved[1]	G—bare	P	51	72	25			
104X	Cromansil	As-rolled			60	82	43		28 (I.)	
		As-welded	G—bare	P	59	86	17		31 (I.)	No
105X	Mayari R	As-rolled			66	82	28	65		
		As-welded	E—M.S. coated	P	71	83	21	42		No
		Stress relieved[2]	E—M.S. coated	W	62	75	23	50		
		Stress relieved[3]								No
105X	Mayari R	As-rolled			55	78	26	61	80 (I)	
(*a*)		As-welded	E—M.S. coated	W	65	82	10	17		No
		Stress relieved[3]	E—M.S. coated	P	59	80	20	35		No
(*b*)	Mayari R	As-rolled			52	69	30	61		
		As-welded	E—M.S. coated	P	56	70	23	47		No
		Stress relieved[3]		P	52	66	25	59		No
107X	Yoloy	As-welded	Yoloy coated rod		66	80	21			
(*a*)	Yoloy	As-rolled			48	71	56**		769 (T. I.)	
		Stress-relieved			45	68	61**		730 (T. I.)	
		As-welded	E—C-Mo coated	P	47	74	16**		788 (T. I.)	No
		Stress relieved	E—C-Mo coated	P	40	74	17**		651 (T. I.)	No
(*b*)	Yoloy	As-rolled			48	61	30	71	42 (I.)	No
		As-welded	G—bare	P	45	62	30			No
		Stress relieved[1]	G—bare	P	63	76	31			
(*c*)	Yoloy (high ductility)	As-rolled			50–55	67–76	29–26*		43	
		Transverse			50–55	67–76	26–23*			
		Weld spec. as-welded	E—Yoloy or C coated		71	80	23	33		
		Weld spec. stress relieved[4]	E—Yoloy or C coated		68	79	28	54		
		Joint as-welded	E—Yoloy or C coated	P	58	76	21	55	30	No
		Joint stress relieved[4]	E—Yoloy or C coated	P	55	72			W 25 B 55	No

TABLE D (*Continued*)

No.	Name	Condition	Type Welding	Fracture	Y.S. M Lb./ Sq. In.	T.S. M Lb./ Sq. In.	% Elong. in 2 Inches	% R.A.	Charpy Impact Ft.-Lb.	Max. Loc. Hardness Over 96 Rock. B
108X	R. D. S.	As-rolled			62	83	25	56	27 (I.)	
		As-welded	G—bare	P	60	97	13			No
		Stress relieved[1]	G—bare	P	61	83	19			
110X	Hy steel	As-rolled			65	77	33	68		
		As-welded	G—bare	P	56	76	27			No
		Stress relieved	G—bare	P	58	76	21			
112X	"AW"-70–90	Normalized			55–65	70–80	25	55	65	
		Annealed			45–50	62–70	25–28	55–60		
		Stress relieved			50–60	65–75	25	55		
		Transv. Norm.			55–65	70–80	25	55	65	
		As-welded[5]	E—bare C	P	54	75	28	62		No
		As-welded[6]	E—bare C	P	63	78	28			
		As-welded[7]	E—bare C	W	63	75	17			
		As-welded[8]	E—bare C	P	62	71	25			
		As-welded[8]	G—$^1/_{16}$ H.T.	P	53	68	13			
		As-welded[8]	G— 3 Ni	P	55	73	16			
		As-welded[5]	G—$^1/_8$ H.T.	W	59	62	5			
		As-welded[6]	G—$^1/_8$ H.T. (back-hand)	P	54	67	18			
206X	Nickel	As-rolled			55 (Min.)	88 (Min.)	15* (Min.)			
			E—Fl. 5				9	11	26	
			E—Fl. 5				8	18	36	
			E—Fl. 5				12	26	38	
			E—Fl. 85				23	32	25	
			E—Var.				10	20	23	
			E—G.E.				12	21	25	
208X	Yoloy	As-rolled			54	87	50**		812 (T. I.)	
		Stress relieved			56	81	52**		797 (T. I.)	
		As-welded	E—C-Mo coated	P	48	84	22**		435 (T. I.)	Yes
		Stress relieved	E—C-Mo coated	P	52	85	22**		727 (T. I.)	
212X	High Tens. Mn	As-rolled			55 (Min.)	88 (Min.)	15* (Min.)			
			E—Fl. 5				9	15	32	
			E—Fl. 5				7	15	36	
			E—Fl. 5				12	23	33	
			E—Fl. 85				10	14	33	
			E—Var.				12	23	21	
			E—M-C Mo				9	16	27	
			E—Wilson 9				7	12	24	
212X (*a*)	Man-Ten	As-rolled			50	80	19		40 (I.)	
		As-welded	E—M.S. coated							Yes
214X	Mn-Mo	As-rolled			55 (Min.)	88 (Min.)	15* (Min.)			
			E—Fl. 5				11	25	32	
			E—Fl. 5				9	21	31	
			E—Fl. 5				12	34	33	
			E—Fl. 85				13	19	30	
			E—Var.				13	24	21	
			E—M-C				11	21	20	
			E—M-C Mo				12	25	27	
			E—G.E.				10	19	29	
215X	Mn-V		E—Fl. 5				17	28	31	
			E—Fl. 5				11	21	33	
			E—Fl. 5				14	32	35	
			E—Fl. 85				23	42	27	
			E—Var.				13	22	27	
			E—M-C				11	18	27	
			E—M-C Mo				34	44	24	
216X	Sil-Ten	As-rolled			36	96	43**		895 (T. I.)	
		Stress relieved			36	89	46**		875 (T. I.)	
		As-welded	E—C-Mo coated		48	97	23**		698 (T. I.)	Yes
		Stress relieved	E—C-Mo coated		44	92	36**		745 (T. I.)	
217X	Cromansil	As-rolled			55 (Min.)	88 (Min.)	15* (Min.)			
			E—Fl. 5				11	21	33	
			E—Fl. 5				9	18	32	
			E—Fl. 5				14	37	35	
			E—Fl. 85				31	44	28	
			E—Var.				10	16	30	
			E—M-C				9	20	29	
			E—M-C Mo				8	16	27	

[1] 1200° F., 1 hr.
[2] 1475° F.
[3] 1050° F.
[4] 1 to 1$^1/_2$ hr. at 1150–1200° F.
[5] $^5/_{16}$
[6] 12 Gage
[7] 13 Gage
[8] 16 Gage

Fl.—Fleetweld
Var.—Various
M. S.—Mild Steel
M-C—Murex-Cresta
G. E.—General Electric
E—Electric
G—Gas
T. I.—Tensile Impact
C—Carbon
P—In plate
W—In weld
* El. in 8″
** El. in 1″

field of activity may wonder that a report on weldability of low-alloy steels makes little mention of welding technique. In effect, such mention would be redundant because within the range of analyses now available and covered in this report the welding technique does not differ from that used in the welding of plain carbon steel in any respect, with the possible exception that the welding rod or electrode may contain small amounts of alloys. This is true because the amount of alloying elements is so low as to have little or no effect on the fluidity of the metal proper or on the nature of the slag formed during the welding operation.

No attempt has been made to draw conclusions from the data here presented, except as such conclusions may be implied by the grouping. The grouping is, however, designated for the general case and may not apply where specific welding conditions and specific welding techniques are involved, and like all generalizations should be used with caution. It is the thought of the committee that the data should speak for themselves and confirm the host of applications of the welded low-alloy steels based on sound engineering judgment.

LIST OF TRANSLATIONS MADE AVAILABLE BY THE WELDING RESEARCH COMMITTEE

(Prepared under the joint auspices of the Fundamental and Literature Division.)

Progress in Welding During the Last Six Months of 1936, by Wilhelm Lohmann—tr. by G. E. Claussen.

Tests of Riveted and Welded Beam Splices Under Repeated Loads, by Otto Graf—tr. by American Institute of Steel Construction.

Investigation of Welded Joints—Effect of Shape on the Fatigue Strength of Welded Joints, by W. Schick—tr. through courtesy of A. O. Smith Corporation.

Autogenously Welded Rail Joint Connections, by Hans Melhardt—tr. by Union Carbide and Carbon Co.

Sensitivity of Steels of Higher Tensile Strength to Welding Cracks, by F. Bollenrath and H. Cornelius—tr. through courtesy of Bastian and Blessing Co.

Atomic Hydrogen Welding, by S. Sandelowsky—tr. by Prof. N. F. Ward.

New Foreign Welding Standards—tr. by G. E. Claussen.

Brazing in a Continuous Furnace with Protective Atmosphere—An extended abstract tr. by G. E. Claussen.

Loss of Material in Flash Welding and Automatic Flash Welders, by E. Rietsch—An extended abstract tr. by G. E. Claussen.

Welding High-Tensile Boiler Steels—Summary of an Article by H. Aysslinger—Abstract by G. E. Claussen.

Welding Aluminum and Its Alloys—An Extended Abstract of Recent German Literature—tr. by G. E. Claussen.

The Fatigue Behavior of Welded Beams as Affected by Shrinkage Stresses—Summary and Conclusions of a Report by Dr. Ing. G. Bierett—tr. by G. E. Claussen.

The Theory of the Web Plate Stiffened on One Side, by Ernest Chwalla and Alexander Novak—tr. by G. E. Claussen.

Contents of and Selected Passages from Schweissverbindungen in Kessel—Und Behalterbau (Welding in the Construction of Boilers and Tanks)—tr. by G. E. Claussen.

The Operation and Calibration of Two Pulsators, by F. Kaufmann—tr. by G. E. Claussen.

Brazing in a Continuous Furnace with Protective Atmosphere, by E. Kuhlmann—Extended abstract by G. E. Claussen.

The Resistance Welding of Light Alloys, by Dr. Henri Portier—tr. by H. W. Rathmann.

What Developments in Welding Should Be Considered in Revising Specifications? By M. Wandelt—Extended abstract by G. E. Claussen.

Study and Control of Oxyacetylene Welds in Aircraft by Dr. Enrico Zavattiero—tr. by G. E. Claussen

Welding of High Strength Steels, by K. L. Zeyen—tr. by M. G. Corson, Union Carbide and Carbon Company.

Thyratron Controllers for Spot and Seam Welding Machines with Rigid Synchronization—Extended abstract of a paper by S. I. Emdin and A. S. Egorov-Kuzmin, of the Scientific Research Inst. for Telemechanics in Leningrad, U. S. S. R.

Calculation of Welds Under Consideration of Constant Deformation Energy, by Ir. N. C. Kist—tr. by Cyril Jensen.

A New Aid in Testing Welds, by R. Berthod and F. Gottfeld—tr. by G. E. Claussen.

Experiments on the Effect of the Shape of the Ends of Welded Reinforcing Plates in Tension Members and Welded Flange Stiffening Plates on Girders, by Otto Graf—tr. by G. E. Claussen.

Fundamental Researches on Welding Heat in Arc Welding Low-Carbon Steel.

Report 1. Theoretical Temperature Distribution During Welding.

Report 3. Effects of Welding Heat on Deposited Metal.

Report 4. Effects of Welding Heat on Base Metal.

These reports were published in 1936 by Professor Minoru Okada, Department of Metallurgy, Osaka Imperial University, Japan. The translation was made available by Professor N. F. Ward, University of California.

Progress in Welding During the First Six Months of 1937, by Wilhelm Lohmann—tr. by G. E. Claussen.

The Rigidity of Welded and Cast Machine Beds, by F. Koenigsberger—tr. by G. E. Claussen.

German Specifications for Welded Highway Bridges—tr. by G. E. Claussen.

What Developments in Welding Should Be Considered in Revising Specifications?

Fundamental Ideas on the Resistance of the Web Plates of Plate Girders to Buckling, by Dr. Ing. Krabbe—tr. by G. E. Claussen.

Proceedings of the Welding Committee of V. D. I. for May 1937—tr. by G. E. Claussen.

The Hot Bend Test, by L. W. C. Gaymans—An abstract tr. by G. E. Claussen.

The Present State of Development of the Surface Pressure Method of Increasing the Dynamic Strength of Metal Parts, by O. Föppl and W. Wagenblast—tr. by General Electric Company.

Sensitivity to Cracking During Welding of Steels Used in Aircraft Construction, F. Bollenrath and H. Cornelius—complete tr. J. B. Johnson, Wright Field.

(*Continued on page 24*)

METAL DEPOSITION IN ARC Welding*

By GILBERT E. DOAN†

I. GLOBULE FORMATION AND DETACHMENT

NO TECHNICAL process of scientific nature continues long to show improvement unless its basic principles are understood and appreciated. It is the purpose of this paper briefly to review some of the basic principles governing the formation and detachment of the globules of metal from the electrode before it falls into and merges with the weld, and to point out a practical method by which these forces can be modified to improve the depositing process in arc welding. It calls attention to the fundamental resemblance of this growth and detachment of metal globules in arc welding to the growth and detachment of liquid drops of water flowing out of a vertical capillary tube. It need not be pointed out that the entire formation of the weld takes place in the liquid state, and that such a study is therefore important.

A diagrammatic sketch of the welding arc is shown in Fig. 1. An actual arc is shown in Fig. 2. There is abundant evidence that the transference of metal from electrode to weld is chiefly in the form of globules. Oscillograms early indicated a periodic short-circuiting of the arc, attributed to the bridging of the arc by periodic globule transfer. Later it was shown[1] that there was insufficient heat at the cathode to vaporize much iron, and therefore it must remain liquid during transfer. Recently Hilpert[2] has succeeded in taking motion pictures in which the globules are clearly visible as they fall through the arc. In Fig. 3 is shown a globule at the end

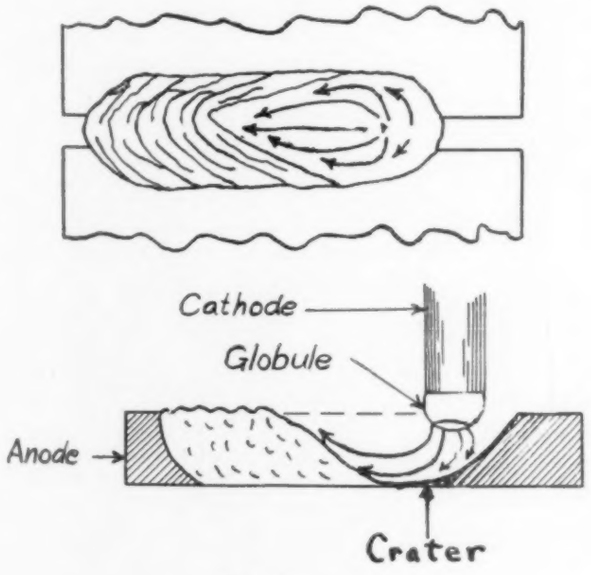

Fig. 1—Welding Arc

Fig. 2—Welding Arc in Argon Showing Pendant Globule

of an electrode after the arc has gone out. Some metal is also transferred in a thread-like formation.

In the course of the discussion which follows, as well as from examination of Figs. 3 and 4, it will become apparent that there is great similarity between the dropping of globules of metal from the end of a melting electrode and the dropping of globules of water as it runs out of the lower end of a capillary tube, or drips from the under surface of a flat disk of the same radius as the tube. The latter two cases of globule transfer have been studied for scores of years by careful experiment and by thorough mathematical analysis. They represent, as compared with the process of arc welding, the ideal case of simple globule formation and detachment free from other complications, such as unquestionably occur in the welding process. As stated in the beginning, it is the purpose of this paper to refer the globule mechanism in welding to the ideal case cited above. The German text, "Kapillaritat und Oberflächenspannung," by Dr. G.

* Contribution to Fundamental Research Division of Welding Research Committee.

† Assoc. Prof., Dept. of Metallurgical Engineering, Lehigh University.

[1] Gilbert E. Doan, Cathode Energy of the Iron Arc, *Trans. A. I. E. E.*, 1930, with discussion by K. T. Compton and R. C. Mason.

[2] A. Hilpert und R. Thun, Zwangl. Mitteilung Nr. 11 des Fachauschusses für Schweisstechnik *Verein Deutscher Ingenieure*. Also *The Welding Engineer*, January 1931. Later Experiments, JOURNAL A. W. S., July 1933.

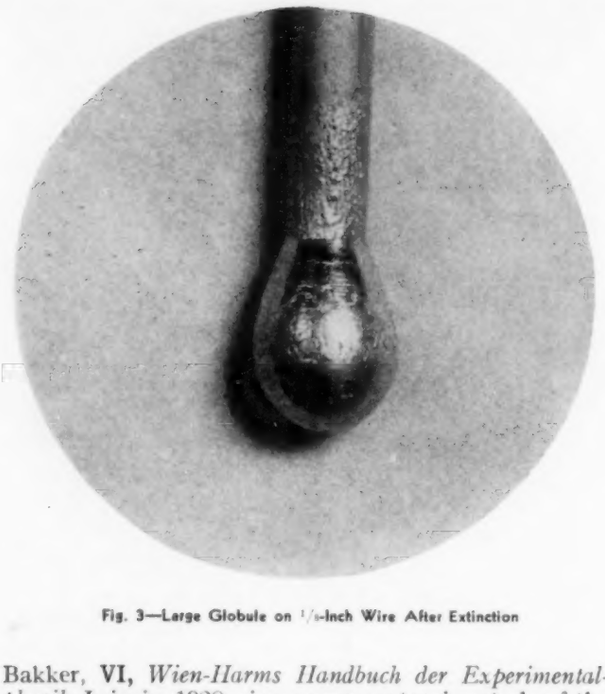

Fig. 3—Large Globule on 1/8-Inch Wire After Extinction

Bakker, **VI,** *Wien-Harms Handbuch der Experimental-physik*, Leipzig, 1928, gives a more extensive study of the ideal case.

The shape of the liquid-solid boundary and the shape and size of the globules themselves are clearly shown in the reproduction.

When a liquid slowly seeps out of a capillary tube, and in fact so slowly that the velocity of the moving liquid can be neglected, then there forms at the bottom of the tube a drop of liquid, at first clinging to the under side of the tube but gradually growing and changing its shape continuously as it grows. Finally, when the drop has reached a certain size, a part of it tears away and falls, while the remainder is left clinging to the lower end of the tube. What is the maximum volume of the drop at which it tears away? What proportion of it tears away and what proportion of it remains hanging? At what point in the pendant drop will be separation occur? What is the relation between these quantities and the capillary constant of the liquid under study?

In the above case where the liquid collects at the lower end of a capillary tube, the surface of the clinging drop may be considered as a surface of rotation. It can be shown that the chief radii of curvature of such a drop are two, called R_1 and R_2. The equation expressing the curvature of these two radii are

$$R_1 = \frac{\left(1 + \left(\frac{dz}{dx}\right)^2\right)^{3/2}}{\frac{d^2Z}{dx^2}} \text{ and } R_2 = \frac{r}{\cos\beta} = \frac{x}{\cos\beta}$$

where x and z are the intercepts of the drop on these axes, r is the radius on the Z axis, and β is the angle at which the tangent to the meridian curve cuts the Z axis.

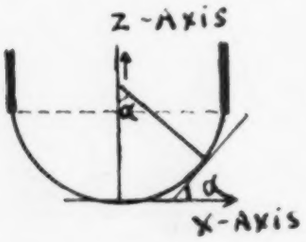

Fig. 4—Meridian of a Hanging Drop

Two cases are of outstanding importance:

If, in the case of Fig. 5, a lying drop, the Z axis is considered as positive in the direction of gravitation, and if we consider for simplicity's sake the presence of only a single medium, that is, no air present, then for the lying drop we get

$$2Z = \frac{a^2}{x}\frac{d(X \sin\alpha)}{dx} - \frac{a^2}{R}$$

in which "a" is the Laplace constant.

In Fig. 4, the hanging drop, where Z is assumed positive when *opposed* to the direction of gravitation, we get

$$h - Z = \frac{a^2}{z} \cdot \frac{1}{x}\frac{d(x \sin\alpha)}{dx}$$

$$\text{where } h = \frac{a^2}{R} \qquad Z + h = \frac{a^2}{2} \cdot \frac{1}{x} \cdot \frac{d(x \sin\alpha)}{dx}$$

Since, for the general surface level the mean curvature is zero, therefore $Z + h$ is the height of the surface level above the point in consideration, and therefore h is the height of this plane above the inversion point "O." This is demonstrated more clearly when one considers the mass of liquid of Fig. 5, not as shown, lying on a horizontal surface but as the liquid in the shorter leg of a system of two communicating tubes, Fig. 6.

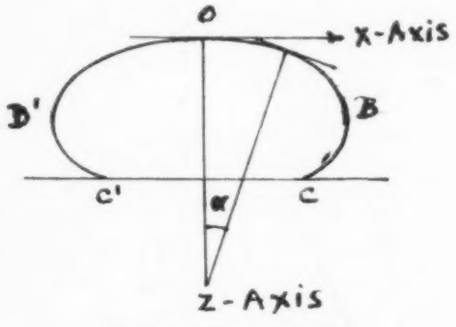

Fig. 5—Meridian of a Lying Drop

II. THEORY OF DROP DETACHMENT

It is, however, not primarily with the clinging drop nor with the lying drop that we are concerned in the welding process, but with the falling drop. It was Lohnstein who devoted his especial attention to drops as they fall from a capillary tube. If r is the radius of the surface of contact between a drop (a rotational body) hanging to a solid body, the original belief was that the weight of the drop was $2\pi rH$, in which no distinction was made between hanging and falling drops. Thus, for example, Quincke[3] calculated the surface tension constants of molten metals by means of the drops which fell from thin wires. His results were only approximately correct.

Lohnstein, in opposition to almost all of his predecessors, goes back to the fundamental theory, the differential equation of the drop surface. Likewise, Harkins and Brown consider the case of a drop with spherical base and use the Laplace-Gauss formula, from which

[3] Quincke, *Pogg. Ann.*, 135 (1868), 638.

they calculate the weight of the drop which separates as follows:

$$Mq = 2\pi r H \psi\left(\frac{r}{V^{1/3}}\right)$$

It is important to note that this formula applies also to the weight of drops which fall from a *surface* of radius r (such as the end surface of an electrode) as well as from tubes of this radius. The drop which they consider is one of spherical surface of radius r, and they assume that the hanging drop separates as soon as its volume has reached a maximum. (H is the capillary constant of the liquid $H = {}^1/_2 a^2 g\rho$) (ρ = density, g acceleration of gravity), V = volume of the drop, r = inner radius of the tube. This weight shows that the older scientists were in error when they believed that a weight of $2\pi rH$ was the maximum drop which a tube could hold. An approximate formula by Lohnstein gives the maximum weight of a drop: $18.84\sqrt{\frac{H^3}{g\rho}}$. For water at average temperature, this formula gives a weight of 0.395 gram. The globules falling from a ${}^1/_8$-inch steel electrode weigh from 0.15 to 0.20 gram each. In order to obtain "freely falling" globules, a longer arc than usual must be held.

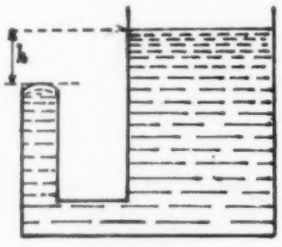

Fig. 6—Equivalent of a Lying Drop

Again Lohnstein asked himself the question: According to what principle does the drop of maximum size separate into the part which falls and the part which remains behind? Without giving his reasons, it is of interest to note that more liquid falls down than was present below the level of the tube end, and the boundary surface after separation must therefore be concave. The writer has sometimes observed this concavity at the end of a steel electrode after the arc is extinguished.

At this point we may raise the question as to the extent to which this ideal process of drop formation and detachment can exist in the welding process, and to what extent it is interfered with (*a*) by gas explosions in the metal globule, (*b*) by unequal heating and cooling of the globule, (*c*) by disturbance of the globule by the arc crater and by the pressure which seems to exist there, (*d*) by the bridging of the globule to the weld crater *before* normal drop detachment can take place, as in "short-arc" welding, (*e*) by the Pinch effect and (*f*) by the presence of a shielding coating extending beyond the end of the electrode tip. Obviously, there are many interferences to obscure the ideal process of drop formation and detachment, and yet the basic processes of drop formation and detachment are the same in both cases. The effect of some of these interferences may be seen by comparing the distorted globules in Fig. 7 and comparing them with Figs. 2 and 3. Any fundamental study of the melting behavior of electrode, and of the formation of the weld, must therefore recognize these basic principles of the classical theory as its foundation.

One of the important indications in the equations for

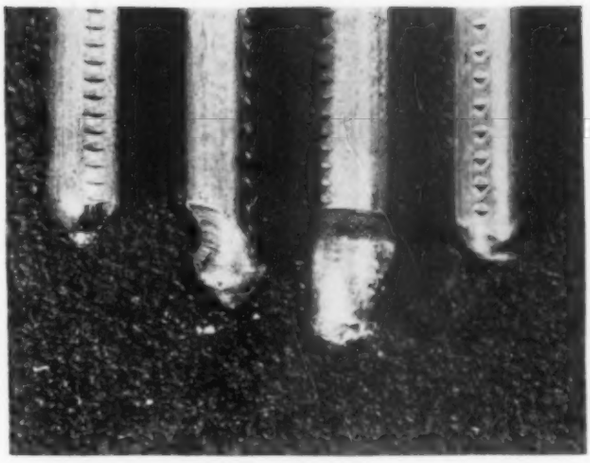

Fig. 7—Stages and Types of Globules Resulting from Interference with Ideal Conditions

hanging and falling drops given above is the fact that H, the surface tension of the liquid in question determines largely the size of the drop which falls. If the surface tension of the liquid steel globule in arc welding could be reduced 50 per cent, each globule would fall from the electrode when only half the size found in normal welding. The most important effect should be a more rapid melting of the electrode. For it is quite apparent that the growth of large globules on the tip of the electrode forms an effective barrier to the flow of heat from the arc to the unmelted wire and thereby retards the melting of the electrode. On the contrary, the instant after a globule has detached, there is left only a thin layer of liquid metal between the arc and the un-

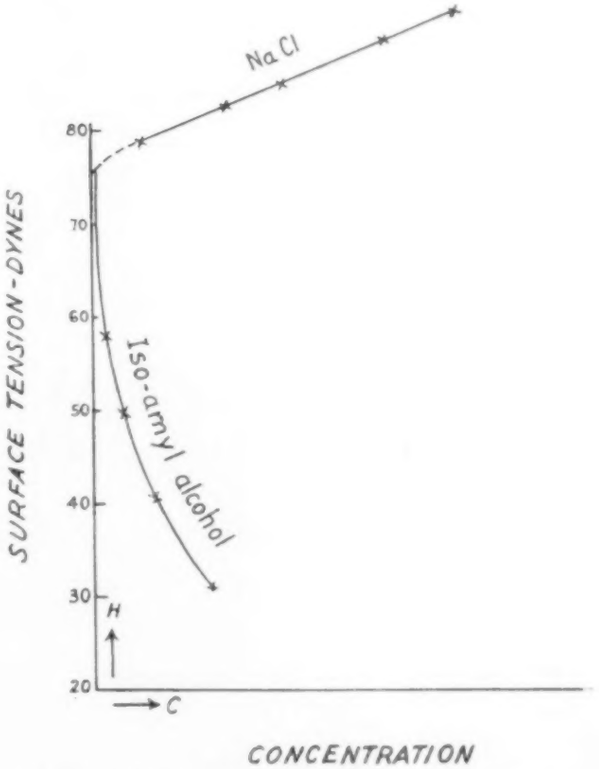

Fig. 8—Surface Tension of Water Solution of NaCl and Iso-Amyl Alcohol as Affected by Changes in Concentration

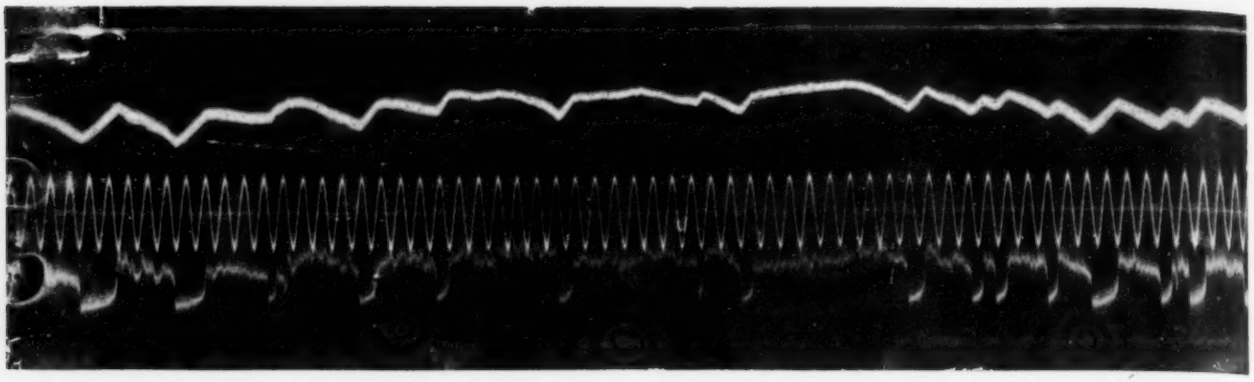

Fig. 9—Untreated Bare Electrode Operation 20 Globules Deposited per Second

melted end surface of the wire. The rate of melting of the electrode tip will, therefore, at this time be very rapid. As the globule grows in length the melting rate of the rod will decrease. With this condition in mind, a search has been made to find a method for lowering the surface tension of the liquid steel at the tip of the electrode, in order thereby to diminish the size which each globule would attain before it detached, and thus speed up the welding process. It was important, of course, that the properties of the finished weld should not be destroyed.

III. SURFACE TENSION OF SOLUTIONS

If one adds to a liquid a substance which dissolves therein, for example *NaCl* to water, then the surface tension of the water will change. In the case of *NaCl*, the surface tension of the solution is increased and its increase is closely proportional to the amount of salt added. In this case larger globules of the solution would form before falling than if the globules were of pure water. In the opposite case, namely, where the surface tension is *lowered* by the dissolved material, the decrease in surface tension is profoundly greater than would be expected. For this reason the former substances are called "inactive capillary agents" and the latter substances "active capillary agents." The difference in the surface tensions of the two solutions is shown clearly in Fig. 8.

That we should expect small increases and large decreases of surface tension follows from Gibbs' equation for the quantity of a substance adsorbed in the surface layer of a liquid:

$$a = -\frac{c}{RT}\cdot\frac{dH}{dC}$$

c = concentration (mol/liter)
H = surface tension
a = the amount of the adsorbed material which is present on one square centimeter of the liquid
R = gas constant
T = temperature in degrees abs.

In the case where the surface tension increases with the concentration a will be negative, so that less of the dissolved substances will be found in the surface layer per unit volume, that in the remaining mass of the liquid, while in the case of lowered surface tension, the substance is adsorbed positively, and therefore the surface layer contains more of it per unit volume than the remaining mass. Since the solution is more dilute at the surface, with inactive substances, therefore the dilution itself must also be small, because the entire quantity of dissolved material is small.

Figure 8 shows the relation between the surface tension of an aqueous solution of sodium chloride and the concentration of salt in the solution. If, on the other hand, a substance is adsorbed positively and therefore decreases the surface tension in Gibbs' equation, it is easy to see why the effect on the surface tension will be greater. For with positive adsorption the quantity of the dissolved substance in the surface layer per unit of volume

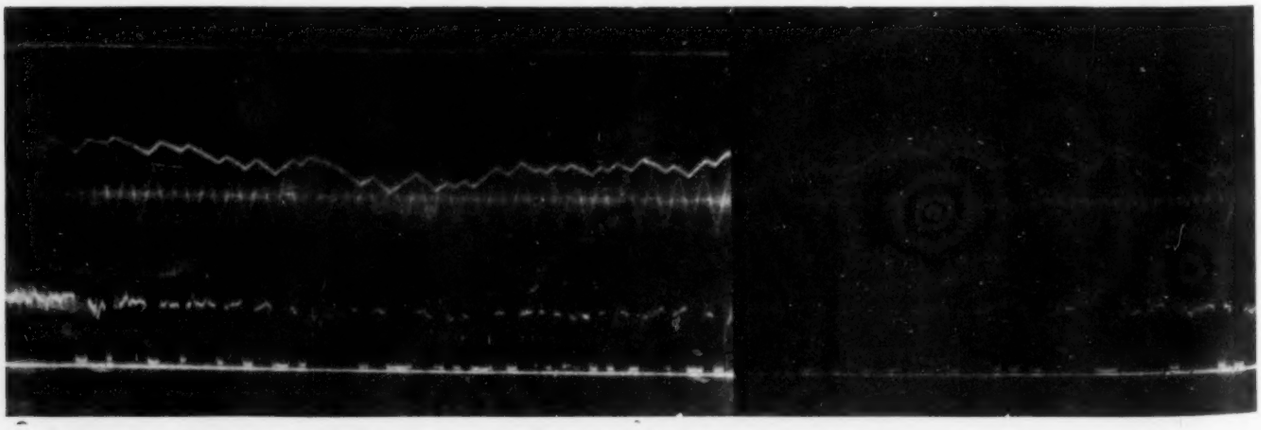

Fig. 10—Electrode Treated to Lower the Surface Tension of the Globules. 48 Globules Deposited per Second

is greater than in the remainder of the liquid, and it is even possible that the entire quantity of the dissolved substance may be in the surface layer of the liquid. As a matter of fact, experience confirms this view: The *H-c* curves of active capillary substances drop off very rapidly from the ordinate of the substance with greater surface tension. In Fig. 8 is given also a typical curve for active capillary substances, in this case Isoamyl alcohol. Usually the drop of the surface tension of the solvent is steeper if the surface tension of the dissolved material is very low.

IV. ACCELERATED WELDING

It should, therefore, be possible by adding to molten steel even a very small quantity of a soluble substance of low surface tension, thereby greatly to lower the surface tension of the steel and the size of the globules formed in welding. As a result, the rate of melting of the electrode, with the same rate of heat supply, should be increased.

In an attempt to produce this result, it was first necessary to examine the surface tensions of liquid metals. The data are rather scanty, but the following are fairly well authenticated,* at least as to relative order of magnitude. Iron is 1244 dynes of tension across each centimeter of surface and copper is 1115. At the other end of the list are antimony 274 or 368, bismuth 343, gallium 358, etc. Experiments were, therefore, carried out with steel rods, both uncoated and coated with one of the metals of low surface tension. The coating was applied in various ways. At first the cleaned rods were dipped into the molten metal. This method being troublesome, the second metal was powdered and suspended in a water solution of sodium silicate. In this case the control rods for checking the results were coated also with sodium silicate, but without the powdered metal. Later, experiments were conducted in electrolytic deposition but the adjustments necessary to prevent a black deposit of powdered metal were difficult to maintain. At last the Schoop process was used and the metal was sprayed onto the rods after they had been thoroughly cleaned. This method gave a uniform, tightly adherent coating without the necessity of using a binder.

The method of testing was simple. It consisted in welding with each rod under the same conditions of current, arc length, etc., employing the same operator in each instance and measuring the length of electrode melted per minute in each case. Repeated tests showed, in the case of a coating of antimony, a rise in melting rate of from 25 to 50 per cent, as compared with uncoated electrodes. To check these results and to see also whether the results were due to reduction in globule size, oscillograms were made of the fluctuations of arc current and voltage during deposition. These fluctuations are caused by the extinction of the arc every time a globule spans the gap. For the globule usually touches the weld before it lets go of the electrode. If the globules are rendered smaller by the surface tension effect of the second metal, the frequency of the extinctions should increase. Figure 9 shows an oscillogram of a normal bare wire welding arc with about 20 peaks per second, corresponding to 20 globule transferences. The other figure No. 10 shows an oscillogram of a welding arc in which the same material was coated to lower the surface tension of the globules. There is an average of 48 peaks per second, which indicates a very much more rapid rate of globule detachment. The smaller size and more frequent deposition of globules thus offer apparently the true explanation of the increased rate of melting of the coated electrode.

The amount of coating material necessary to accomplish this accelerated melting is very small, as would be indicated by the curves in Fig. 8 above. Very much less than 1 per cent, and in some instances as little as $^1/_{10}$ of 1 per cent, is sufficient. Naturally such a small quantity, after passing through the arc, has, so far as we have determined, very little, if any, influence on the physical and chemical properties of the weld.

The present instance of an improvement in a useful art is cited as an example of the expediency of planning an improvement in a physical process on the basis of well-proved theoretical foundations. The success is not always obtained as strikingly as in this case because of unexpected secondary conditions which enter into the operation and which may interfere with the results planned. This example will illustrate, however, the advantage in beginning such a study in a fundamental way.

In this instance it has made possible the more rapid conduct of the welding operation. It would seem applicable also to the heavily coated electrodes now widely used.

ACKNOWLEDGMENT

The author is indebted to Mr. A. M. Bounds, graduate student, for the photographs appearing in the paper.

* Sauerwald: "Lehrbuch der Metallkunde," Berlin, 1929.

(*Continued from page 1*)

the wrought iron base metal weld outside the weld zone, both for wrought iron to wrought iron, and for wrought iron to mild steel specimens. Failure occurred in base metal because the weld metal had higher strength.

The specimens for the tensile tests were 3 inches wide, 24 inches long. For a distance of 6 inches on either side of the weld the width was reduced to 2 inches to provide a reduced section 2 inches wide, 12 inches long. The shear test specimens were welded with $^1/_2$-inch fillets.

The expression "Aston process" should be deleted from the first sentence of the first paragraph of the right-hand column, page 72, referring to tensile properties of wrought iron at elevated temperatures.

Laboratories Form an Association

Representatives of twenty of the principal commercial laboratories of the country, at a meeting in Chicago recently, completed the organization of the American Council of Commercial Laboratories. One of the purposes of the Council will be the promotion of the proper use of scientific testing methods for the protection and certification of quality in advertised goods.

In behalf of the Council it is stated that the members have been and will be carefully selected to include only organizations to which producers, retailers and consumers may look for unbiased determinations of quality. Engaging in research and testing for fees these independent laboratories ascertain and report facts for clients and are uninfluenced by any ulterior consideration.

Laboratories which are adjuncts of other enterprises, or which are not self-supporting, or which, for any reason are not independent are ineligible for membership in this council.

The following officers and members of an executive committee were elected to serve during 1938:

President, Preston S. Millar, Electrical Testing Laboratories, New York, N. Y.

Vice-President, Monroe L. Patzig, Patzig Testing Laboratories, Des Moines, Iowa

Secretary, D. E. Douty, United States Testing Company, Hoboken, N. J.

Treasurer, A. R. Ellis, Pittsburgh Testing Laboratory, Pittsburgh, Pa.

PROGRESS IN WELDING

By WILHELM LOHMANN

During the First Six Months of 1937*

Published in *Stahl und Eisen*, 57, No. 38, September 23, 1937, pages 1051–1055

I. MATERIALS

THE metallurgy of welding has been studied by T. Swinden.[1] The same conditions are encountered in welding as in steel melting. In the absence of carbon, oxygen acts to form blow-holes, whereas nitrogen tends to suppress them. In this respect nitrogen acts like argon to free the melt from hydrogen and thus to remove the cause of blowholes. Concerning deoxidation the author believes that the filler rod should contain little or no silicon. In arc welding the silicon reduced from the coating provides sufficient deoxidation. In gas welding, on the other hand, a deoxidized steel is preferred and the rod should contain silicon and manganese in suitable proportions. The behavior of the filler rod is particularly satisfactory if the steel is first deoxidized with manganese and then killed with silicon. Although little is known about the effect of scrap in the charge, this factor seems to have an important effect on gas content. The author believes that the hydrogen content should be given as much attention as the nitrogen and oxygen content.

Discussed in an earlier review,[2] the use of austenitic electrodes for unalloyed and low alloy steels has been dealt with again by K. L. Zeyen[3] who has formulated a set of instructions. In both gas and arc welding the conduction of heat from the weld must not be too rapid, otherwise shrinkage cracks will occur in the weld. Material thicker than 0.59 inch should be preheated to 150–200° C. Gas welds should not be puddled. Torch and filler rod are smaller than for welding mild steel. Cracks will not occur in craters in arc welding if the craters are welded up. Current is critical and cannot be varied except within narrow limits. The electrodes commonly used are 0.12 to 0.20 inch diameter; 0.24-inch electrodes are used in exceptional cases. Short electrodes must be used for vertical and overhead welding. The coating must be dry. Types of pipe joints which permit the formation of icicles on the inside should be used only in conjunction with backing rings. The overhead welding should always be done first in the position welding of pipes.

Welding in the oil industry is discussed by R. K. Hopkins.[4] The requirements placed on welds are severe because temperatures from −60 to + 650° C. and pressures from 3 to 1200 psi are encountered. The riveted joint in America has been superseded almost entirely by the hammer-welded or fusion-welded joint. The material to be used depends on the pressure, the temperature and on the corrosive effect of the petroleum, which in many cases contains sulphur compounds. Whereas silicon-killed plain carbon or silicon-killed 0.5% Mo steels are in general use, 2¼% nickel steel is used for low temperatures. The author believes that plain carbon steel deoxidized by special methods also has adequate toughness at low temperatures. Mild steel is satisfactory to resist mild corrosive attack, but in highly corrosive environments other steels must be used. The best steels are the chromium steels (6 to 14% Cr) and the stainless chromium-nickel steels. Corrosion resistance may also be raised by spraying with aluminum, coating with cement, or cladding by rolling, or by chromium plating. All these expedients are very expensive and may often be avoided by using a less costly material in thicker sections.

According to A. E. Gibson,[5] the requirements for weldable high strength steels are: high yield ratio, high fatigue strength, corrosion resistance several times that of plain carbon steel, low tendency toward hardening in the heat-affected zone, and capacity for heat treatment. To a large extent these requirements are fulfilled by copper-nickel steels, produced with a minimum copper content of 1% by three American firms. The nickel varies from 0.5 to 2%. From the standpoint of metal economics, steel of this composition is out of the question in Germany at the present time, but the results are worth mentioning. Depending on carbon content (0.10 to 0.20%), the tensile strength varies from 71,000 to 92,000 psi, with a yield ratio of 85% and an average elongation of 25%. Welds are made either with an electrode containing molybdenum (0.7 Mo, 0.5 Ni, 0.3 Cu) or with an electrode having the same composition as base metal. In the majority of cases the copper-nickel steel electrode is entirely satisfactory because there is practically no loss of copper in welding and the nickel recovery is about 90%. As a matter of fact, the properties quoted by Gibson for the unwelded base metal also applied to the welded material. Hardening in the heat-affected zone was extraordinarily small and, despite the high strength of the steel, differed but little from a low-alloy steel having a minimum tensile strength of 74,000 psi (*ST* 52). The corrosion resistance in liquid media was about four times as great as that of mild steel. After being normalized, only the bend ductility and notch impact value of the weld was appreciably different from base metal.

The formation and occurrence of nitrogen in welds is discussed by A. Portevin and D. Séférian.[6] Dilatometric investigation of specimens with different nitrogen contents up to 0.25% showed that the iron-nitrogen constitutional diagram determined by Fry was not correct. In the absence of other nitride-forming elements, nitrogen appears as needles of Fe_4N. Corresponding to the structures found in iron-carbon alloys, the authors found that nitro-ferrite, nitro-martensite and nitro-

* Translated by G. E. Claussen Research Assistant, Welding Research Committee.

austenite may be produced by appropriate heat treatment. Nitrogen pick up and formation of nitrides are affected by a number of factors. As is well known, a long arc (high voltage) favors nitrogen absorption. Alternating current also increases nitrogen pick up. Coated electrodes decrease the nitrogen pick up; the best effect was achieved by the authors if the cross section of the coating was one-half that of the electrode. Thicker coatings have little additional effect in decreasing the nitrogen pick up. It was also found that there is about the same nitrogen pick up in nitrogen and ammonia as in air. Alloying elements affect the pick up of nitrogen. Carbon, silicon, and especially manganese decreased the pick up, whereas aluminum and chromium, which are nitride forming elements, greatly increased the pick up. Sulphur and phosphorus appeared to have no effect on nitrogen pick up.

In another paper A. Portevin and D. Séférian[7] made a thorough investigation of the effect of alloying elements on nitrogen pick up in arc welding. Hydrogen and coatings up to a critical thickness decrease the absorption of nitrogen. The effect of carbon, manganese, silicon, aluminum, chromium, molybdenum, titanium, vanadium, zirconium and uranium on nitrogen pick up was investigated with a coating containing 47% Fe_2O_3, 40% H_4SiO_4 and 8% Al_2O_3. The alloying elements were added partly to the coating, partly to the electrode. The electrodes were made of as pure materials as possible. It was found that carbon, silicon, managnese and titanium decreased nitrogen pick up, whereas molybdenum, zirconium, chromium, aluminum and vanadium increased the pick up in the order of their effectiveness. Although definite information was not secured, it was believed that uranium had no effect on nitrogen pick up. The authors were able to detect the nitrides of titanium, zirconium, vanadium and uranium by micrographic means. Nitrogen refines the grain structure of chromium steels; otherwise chromium steels are difficult to weld on account of excessive grain growth. It is the reviewer's opinion that a coating with high iron oxide content is not suited for the study of nitrogen pick up as affected by alloying elements. Indeed, if low nitrogen content is desired the coating should not contain iron oxide.

The cold welding of cast iron is performed by S. W. Jernilow[8] with the aid of a covered electrode containing 3.2% C, 5% Si, 0.5% Mn, 0.3% P, 0.06% S. The composition of the coatings is given in Table 1. Water glass was used as binder. The author's results show that the rods have good weldability, and that the welds are not porous and have good machinability.

Table 1—Composition of the Coatings Used by S. W. Jernilow for Cold Welding Cast Iron

% Composition	I	II	III	IV	V
Carborundum	65	40	50	..	..
Graphite	17	30	25	25	30
Aluminum	15	3	5	5	5
Barium Carbonate	3	..	..	..	..
Chalk	..	17	20	20	15
Jeweller's Rouge (iron oxide)	..	10	..	..	10
Ferro silicon	..	..	..	50	40

II. METHODS

In an earlier review[9] a discussion was given of different methods for decreasing the cost of gas welding. Experience with one of these methods, namely, welding simultaneously on both sides of a plate, in the construction of tanks up to 1800 cubic feet capacity is recounted by R. Meslier.[10] Wherever possible the welding should be done vertically. Plates up to 0.47 inch thick need not be beveled in any way. Two welders weld simultaneously on both sides of the joint; heat is conserved in this way and smaller torches using less gas may be used than in the ordinary method of welding on one side. The consumption of welding rod is also smaller in the two-sided vertical method than in older methods, so that, if necessary, a more expensive, alloy-filler rod may be used without an increase in over-all cost. If instructions are carried out there are fewer defects than in welds made on one side. Longer tips are required for the two-sided method than for other methods. The gas pressure also must be larger than for one-sided welding (at least 8 inches of water) to prevent overheating of the torch. The gas pressure determines the required size of tip. The author describes a number of devices for facilitating the welding of tanks, and illustrates his article with photographs of a number of successful pieces of work.

Boiler welding, which places the highest requirements on materials and workmanship, is discussed by S. F. Dorey[11] from the standpoint of practical experience. Silico-manganese steel is preferred as base metal, but the silicon content must not be so high that the heat-affected zone becomes brittle. The manganese content may be up to 1%. The electrode should yield a deposit containing not over 0.015% nitrogen, and not over 0.05% oxygen. The FeO content is not stated. These requirements correspond with the requirements for welded boilers in Germany for which a factor of 0.9 is applied to the design strength of base metal. The welds should be U shaped with reverse run, the ratio of maximum breadth of weld to thickness of plate being 0.7 to 0.8. A backing strip should be used for the first run, according to Dorey, in order to prevent dripping. The reverse side of welds in highly-stressed drums should be chipped out up to the second run of weld metal. Several valuable hints are given for welded boiler construction. Dorey states that automatic welding is preferable to manual welding, especially from the cost standpoint. It is the reviewer's experience that at the present time any attempt to increase the diameter of the electrode or the speed of welding is at the sacrifice of quality.

It is well known that the sawing of austenitic steels is very difficult. A satisfactory method for flame cutting stainless steels is described by F. Judelsohn.[12] The method resembles the flame cutting of cast iron. The torch is given a back and forth motion. The torch is first moved forward 0.06 to 0.08 inch; it is then moved backward about 0.04 inch, each forward and backward motion requiring about 1 second. It is not necessary to use an iron wire as in the cutting of cast iron. The thickness of the cut is about $^1/_2$ inch in thick material (the author has cut pieces 5 and 13 inches thick). The appearance of the cut is not described. However, the method costs only 5% as much as sawing.

A discussion of poor penetration and accompanying notches in vertical welds and fillet welds is given by K. Meller.[13] The notches in question are those created by the failure of the molten metal to remain completely in place. Tests with the carbon arc showed that the weight of the molten metal accounts for the notches and that current and voltage are important factors. On the other hand, tests with a good grade of bare electrodes showed that even at high currents and high voltages (long arcs) no notches are formed. Consequently these electrodes do not tend to flow out of place once the metal has been deposited. The behavior of dipped and covered electrodes depends on the character of the coat-

ing. The fact that covered electrodes are often easy to deposit without notches on vertical plates is explained by the high arc voltage, the high concentration of heat and the high viscosity of the molten material. It is more difficult to obtain a satisfactory deposit on a vertical surface with alternating current than with direct current. It is the reviewer's opinion that electrical conditions exert the most important influence, that is, the short circuit behavior and the globule size, related thereto. Both the core rod and the coating affect the electrical conditions.

Don Llewellyn [14] describes a method for building up worn teeth on steam shovels and dredge buckets made of 14% manganese steel. The teeth are first covered with spring steel. Layers of stainless steel are deposited on the spring steel. Finally the profile is built up to shape with a high-carbon electrode and a final layer of air-hardening steel is deposited. The stainless steel layer assures good junction with base metal and succeeding layers.

III. METHODS OF TESTING

Many tests have been made on the advantages and disadvantages of the roller bend and free-bend tests for welds, but the question has yet to be definitely settled. The reason appears to lie in the wide scatter in the quality of welds. The tests by R. Mailänder and W. Ruttmann[15] therefore are of particular value because they tested unwelded specimens. However, the results on unwelded specimens should not be carelessly applied to welds without considering the limitations. The tests were made on two steels (0.1% and 0.5% C) with increasing ratios of plunger diameter to plate thickness or distance between supports. The harder steel was heat treated to different degrees of toughness by quenching in water from 830° C. and drawing at different temperatures. The tests showed that reproducible results could be obtained with any set of testing conditions for a given material. Nevertheless with a large ratio of plunger diameter to plate thickness, there is a very large increase in bend angle and in scatter of results for a small increase in ductility. Whereas there is practically a linear relationship in the free-bend test between maximum elongation and bend angle at the higher values of bend angle, this is not true for the plunger bend test. The difference between maximum elongation and bend angle decreases with increasing ratio of plunger diameter or distance between supports to plate thickness. None of the test conditions investigated produced a uniform distribution of elongation on the tension side. Furthermore, the results with different test conditions differed greatly. It appears that the plunger may adversely affect the capacity of a material for deformation. There is nearly a parabolic relation between the least radius of curvature of the plunger and the maximum elongation. It would be desirable to continue the authors' experiments using welded specimens.

The possibilities of magnetic methods for detecting defects are dealt with by J. W. Yant.[16] For tanks, it is most desirable to magnetize the entire part, assuming, of course, that its dimensions permit several windings of high current cable to be made. For a drum 8 feet in diameter, 40 feet long, 1.6 inches wall thickness the author recommends eight turns and a current of 300 amperes. The current may be supplied by a welding outfit. Naturally, only defects perpendicular to the magnetic field can be detected with certainty. The inspection, therefore, should be made with winding axial as well as radial with respect to the circumference. In order to eliminate the effects of surface irregularities, Yant states that powder should be strewn over the magnetized surface and a light air blast used to blow away any chance aggregations of powder not caused by the magnetic field. This method is useful for tanks, all parts of which are easily accessible. A U-shaped electromagnet is used for testing less accessible parts in small sections. The use of electrodes is also possible, the current flowing locally through the part creating its own magnetic field. The distance between electrodes is adjusted in accordance with the wall thickness and a magnetic field is set up perpendicular to the direction of current. Defects are revealed where the lines of force leave the surface. The author has observed that this method does not reveal defects at any distance below the surface. The method is only good for detecting defects that extend to the surface but that cannot be detected by other methods. The method is useful for inspecting fusion welded flanges and manways.

The magnaflux method is described by T. C. Rathbone [17] and R. F. Cavanagh.[18] The former confines his attention to fatigue cracks, whereas Cavanagh discusses the testing of pressure vessels. Needle shaped, 100-mesh iron powder is used in oil emulsion. The emulsion or else the powder in finely divided form is blown on the surface to be inspected by means of a puff of air. From the shape of the resulting pattern conclusion may be reached concerning the position and depth of the defects. Although the surface need not be ground, slag or rust should be brushed off. About 2000 ampere turns is required. It is not desirable to oversaturate the part (too strong magnetization) because lines of force then leave the surface even if there are no defects. In many cases remanent magnetism is sufficient. Circumferential welds are inspected with electromagnets. The author describes a number of defects, such as cracks around rivet holes, which have been detected by magnaflux.

A magnetic inspection method for welds is described by R. Berthold and F. Gottfeld [19] in which alternating current supplied by two electrodes is passed locally through the part to be inspected. The only new feature is the use of the magnetic powder in oil emulsion to decrease the friction between particles. As the author states, and the reviewer confirms this, the method will not reveal defects that lie more than 0.08 to 0.12 inch below the surface. Thus, the value of the method for welded joints is seriously limited because shrinkage cracks and other defects in welds that reach the surface can generally be seen with the naked eye.

IV. PROPERTIES OF WELDS

The advantages of A.C. welding have been stated on a number of occasions especially in foreign countries,[20] but no impartial tests appear to have been made. C. Stieler [21] has investigated A.C. and D.C. welds in a number of different steels made with a large number of commercial electrodes ranging in tensile strength from 48,000 to 74,000 psi (S_T 34, 37 and 52). The factors studied were arc voltage, melting speed, recovery of elements, loss by spatter, the behavior of the arc, and the mechanical properties. Since the voltages delivered by transformers are usually higher than the voltages supplied by generators, A.C. welding is more dangerous than D.C. Still, to the reviewer's knowledge, no accidents caused by A.C. have yet been reported. The melting speed, alloy recovery, and spatter seem to be a question

of the individual electrode. No difference could be found between A.C. and D.C. Magnetic blow is not encountered in A.C. welding. Frequency curves of the technological properties required in the specifications of the German Railways showed that with satisfactory electrodes there was no difference between A.C. and D.C. With electrodes of lower quality the D.C. welds were more satisfactory than the A.C. There was no difference in the structures of A.C. and D.C. welds. All in all, leaving capital investment, which is lower for transformers than for generators, and bare electrodes out of the question, A.C. welding seems to possess definite advantages.

The hardenability of case carburized welds has been investigated by A. Roux.[22] Oxyacetylene and arc welds were made with different filler rods which differed principally in carbon, silicon and manganese content. Beads deposited on the surface of a soft steel were carburized in solid compound. The hardenability and tendency to soft spots were studied with the aid of the Rockwell tester (*C* scale). Aside from the carbon content, the manganese content of the weld metal is particularly important. All welds with low manganese tended to show soft spots; with higher manganese the deposits had good hardenability. The thickness of the coating is also important, for it affects the oxygen pick-up during welding. Specimens with sufficient manganese but deposited with dipped electrodes showed a tendency to soft spots, although to a relatively small extent. The author states that the results are confirmed by specimens case carburized in liquid media.

The effect of thermal shrinkage stresses on fatigue strength has been studied by A. Thum and A. Erker.[23] Specimens of mild structural steel with and without drill holes were locally heated with a welding torch so that a non-uniform stress distribution over the cross section of the bar was produced, which resembled the shrinkage stress distribution in welds. Specimens without drill holes suffered a slight loss of fatigue strength, which, however, was within the limit of scatter of fatigue results. In view of the fact that the magnitude of the shrinkage stresses was not determined it is impossible to draw conclusions, especially because it is known that shrinkage stresses are decreased by fatigue loading. In the drilled specimens tensile shrinkage stresses at the edge of the hole increase the stress concentration factor, whereas compressive shrinkage stresses decrease it. Consequently, tensile shrinkage stress at the edge of the hole decreases the fatigue strength, but compressive shrinkage stresses at the edge of the hole increase the fatigue strength.

Table 2—Composition of Steels Tested by J. Brillié, A. Leroy and A. Roux

Steel	% C	% Si	% Mn	% P	% S	% Cr	% Cu
X	0.25	..	0.27	0.013	0.051	..	..
S	0.33	0.02	0.54	0.019	0.024	..	..
A	0.13	..	0.49	0.016	0.040	..	0.40
D	0.20	0.27	0.70	0.026	0.031	0.52	0.57

Corrosion tests of the welded steels listed in Table 2 were made by J. Brillié, A. Leroy and A. Roux[24] in 20% sulfuric acid and in artificial sea water. Oxyacetylene and arc welds were made, partly with unalloyed filler rods, partly with rods containing chromium, copper and nickel. All electrodes were covered. Polished or sand-blasted welded specimens were compared with unwelded base metal, the extent of corrosion being estimated by appearance, decrease in dimensions and loss in weight. In 20% sulphuric acid the steels as well as the welds showed great differences. Best results were obtained with the copper and chromium-copper steels. Likewise the welds containing copper, chromium or nickel had the highest corrosion resistance. The smallest difference between the corrosion resistance of weld and base metal was exhibited by steel *A* with all filler rods. Preferential attack in the heat-affected zones was observed in the welded specimens. The zone was much narrower in arc welds than in gas welds, showing that the heat effect has a bad effect on corrosion resistance in sulphuric acid. There were no great differences between the welded and unwelded specimens, whether the weld was more or less corrosion resistant than base metal. Corrosion after 288 dips of $^1/_4$ hour duration in artificial sea water was estimated in the same way as for sulphuric acid. Of the base metals, the unalloyed steel *X* was more resistant than the alloyed structural steel. The same was true for welded specimens. On the other hand, the welds made with unalloyed rods were considerably less corrosion resistant than welds made with alloyed rods. Slag inclusions and porosity had a bad effect on corrosion resistance. In this respect the welds containing 1.6 and 3.25% Ni were superior to the others. Preferential attack of the heat-affected zone was not observed in specimens tested in artificial sea water.

A report by G. C. Ellinger and L. C. Bibber[25] deals with the corrosion resistance of welded stainless steels. Copper sulphate, which causes intergranular corrosion if the carbon content is too high, had no effect on base metal or weld in these tests. Concentrated nitric acid attacked the zone heated to 650° C. where carbides were present in the grain boundaries. The weld was not attacked because the carbides were dissolved in delta iron, regardless of the heat treatment. Hydrochloric acid with water in the ratio 1:1 always corroded the base metal rapidly. In the as-welded condition the weld was attacked at the same rate as base metal, but after heat treatment at 650 or 980° C. the weld was more resistant to corrosion than base metal.

V. MISCELLANEOUS

A comprehensive and fundamental study of flash welding has been made by H. Kilger.[26] There are three stages to flash welding: preheating, flashing and push up. The factors involved in preheating and push up are quite clear but hitherto the flashing process has been puzzling. Kilger's investigations showed that some points of contact are heated to the vaporization temperature on account of the high current density. The vapor explosion gives rise to the well-known spatter or flashes in flash welding. This process is repeated as the bars are moved toward each other during the flashing period. In this way the surfaces to be welded are brought to the welding temperature. The author cites several examples to show that incorrect adjustment of the flash welding machine may give rise to incomplete welds. The investigation of the flashing process and of the dependence of welding on the current conditions at the surfaces to be welded showed that the maximum weldable cross section is 62.5 to 78 square inches. The original report should be consulted for details of the investigation.

Aside from the properties of the electrode, the stability of the arc, according to J. C. Osborne,[27] depends on the static and dynamic characteristics of the welding machine. The dynamic characteristics may best be determined by the following method. Instead of the arc, a resistance of the same ohmage as the arc is introduced into the circuit and short circuited during one period.

The voltage and current conditions during short circuit reproduce conditions during globule transition in the arc. The author states that high induction is favorable to the stability of an arc. With respect to the dynamic (volt-ampere) characteristics of the machine, induction raises the voltage and consequently has an important effect on the striking velocity. Contrary to opinion expressed hitherto that the presence of scale, oil or paint requires a high open circuit voltage, Osborne points out that the open circuit voltage need only equal the striking voltage because the arc can be drawn only from metal to metal. On short circuit the voltage suddenly drops and the velocity with which striking voltage is recovered on withdrawing the electrode is important for the drawing of an arc. The welding voltage also has a considerable effect on the length of arc that may be drawn. A long arc has a bad effect on the smoothness and quietness of welding. Sticking of the electrode to base metal is usually caused by the inability of the machine to build up striking voltage rapidly enough. Summarizing, Osborne requires that the short circuit current must not vary from the welding current beyond the limits + 100% and − 10%. Furthermore, the static voltage must not exceed 85 to 90 volts nor be less than 50 volts.

The action of fluxes in arc welding is discussed by D. L. Mathias.[28] The ability to draw and hold an arc depends on the conductivity of the mixture of gases between the poles. The principal factor governing the conductivity of the gases is ionization. It is well known that lime on bare electrode stabilizes the arc. Other oxides of similar behavior are used as coatings. In general, it has been found that the higher the element stands in the electromotive force series, the greater is the extent to which it gives up electrons and facilitates welding. With a lime coating Mathias found that the deposition velocity was 25 gm./min.; with titanium oxide as coating the velocity was 53 gm./min. On the other hand, the depth of penetration is inversely proportional to the welding speed. The action of thin coating is generally confined to these purely welding effects. Thin coatings do not have sufficient effect on the arc gases to prevent the formation of oxides and nitrides. Kjellberg was the first to show the action of thick coverings. Although the composition of electrodes has changed as new facts have come to light, the commercial electrode today still depends on the protective action of the shield on the end of the electrode for protection against the atmosphere. The toughness of covered electrode welds accounts for the widespread acceptance of the covered electrode. The fundamental constituents of coatings are usually silica, iron and manganese oxide, hornblende, feldspar, titanic acid or rutile. The usual constituents for alloying with the rod are ferro-silicon, ferro-manganese or silico-manganese.

A comprehensive review of literature to Oct. 1, 1936, on Fatigue Tests of Welded Joints by W. Spraragen and G. E. Claussen[29] deals with the following subjects: fatigue as affected by shape of weld; relation between fatigue strength and other physical properties of welds; influence of defects; effect of mechanical and heat treatment; effect of composition; corrosion fatigue; methods of design; repeated impact tests; rail joints; shrinkage; fatigue tests on structural elements; comparison between welding and riveting; fatigue tests on bridges, tubes, etc. This review should be of value to all interested in these questions.

In another report, W. Spraragen and G. E. Claussen[30] review the literature on cast-iron welding to November 1936. The subjects dealt with are: welding processes; non-ferrous filler rods; metallurgical basis of cast-iron welding; properties of welds made by different process; welding cast iron to other metals; flame cutting cast iron; suggestions for further investigation in this direction.

Details of welding in the construction of Ford V-8 trucks are supplied by A. Di Giulio.[31] Welds are made at 3800 locations, of which 92% are spot welds, 3% arc, 2% gas and 3% resistance. Spot welding depends on the quality of the electrode, which must have high thermal and electric conductivity, high hardness, high impact toughness and great wear resistance at elevated temperatures. Pure copper cannot be used on account of its low hardness and low wear resistance. Although the electrodes developed by Ford have lower thermal and electric conductivity than copper, they behave much better in service. The hardness and wear resistance are increased by precipitation hardening alloys. Details concerning these alloys are not divulged. Lately these alloys have been cast and finish machined to shape.

New developments in spot-welding equipment are described by F. Hoch.[32] A number of welding devices have been developed for large or inaccessible parts for which stationary machines are not fitted. The original must be consulted for details.

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(*Translations continued from page 14*)

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